XMC 750 Watt Motor Control Application Kit

Getting Started
PMSM Motor Sensorless dual shunt Field Oriented Control (FOC)
(PMSMFOCSL02)

Agenda (1/2)

- Kit Overview
- Tooling Overview
- Getting Started
  - Chapter 1: Generate PMSMFOCSL02 template
  - Chapter 2: Configure CCU4 as Debugging feature
  - Chapter 3: Motor Electrical Parameters Measurement
  - Chapter 4: Driving Ventilation Fan Application
  - Chapter 5: Driving Ceiling Fan Application

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Agenda (2/2)

- Summary
- General Information
- References
  - Where to find Apps documentation?
  - Where to download example projects?
  - How to load Example project in DAVE?
  - How to improve compiler performance?

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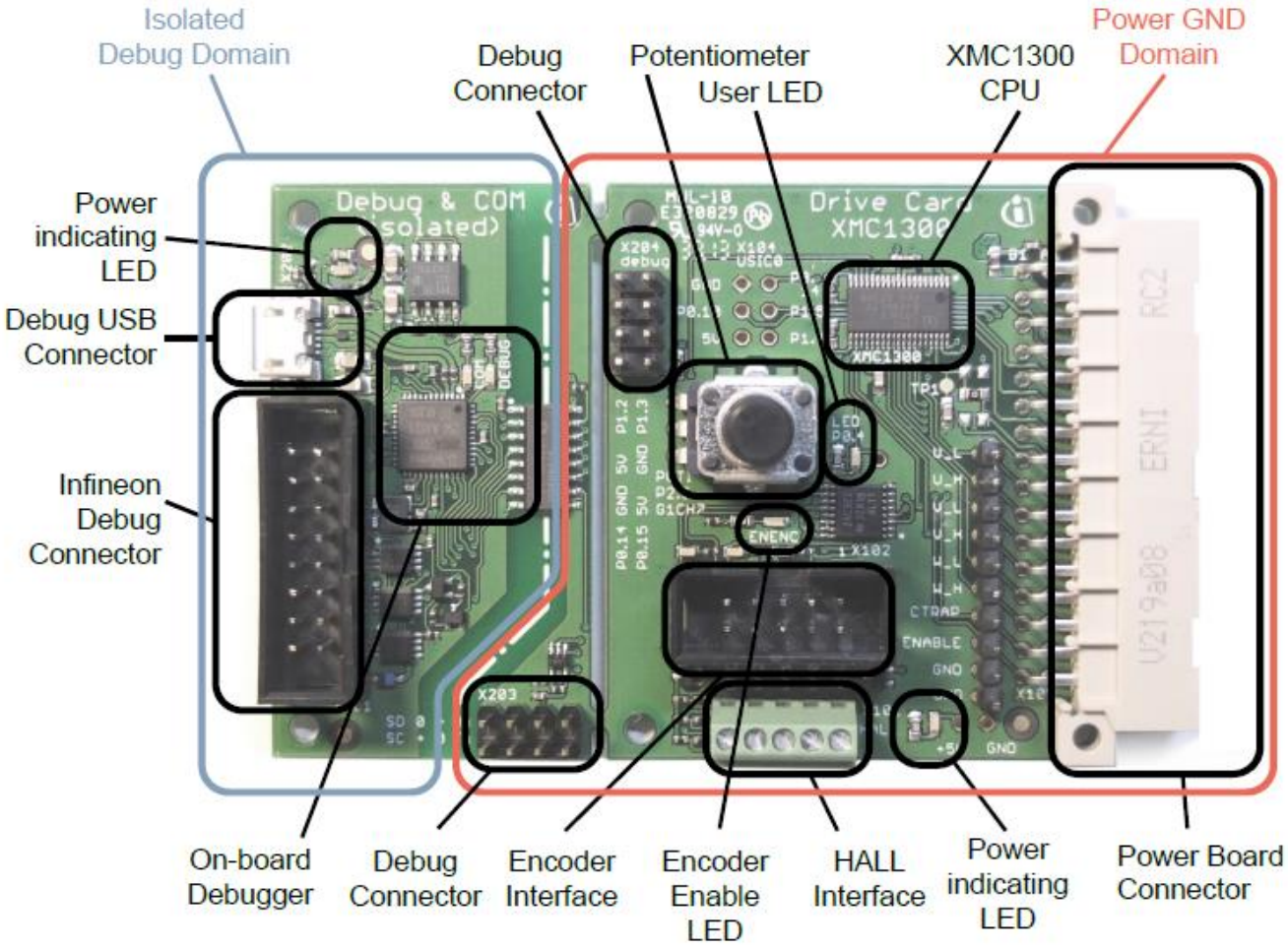
Kit Overview (1/3)

- XMC1300 Drive Card with galvanic isolation



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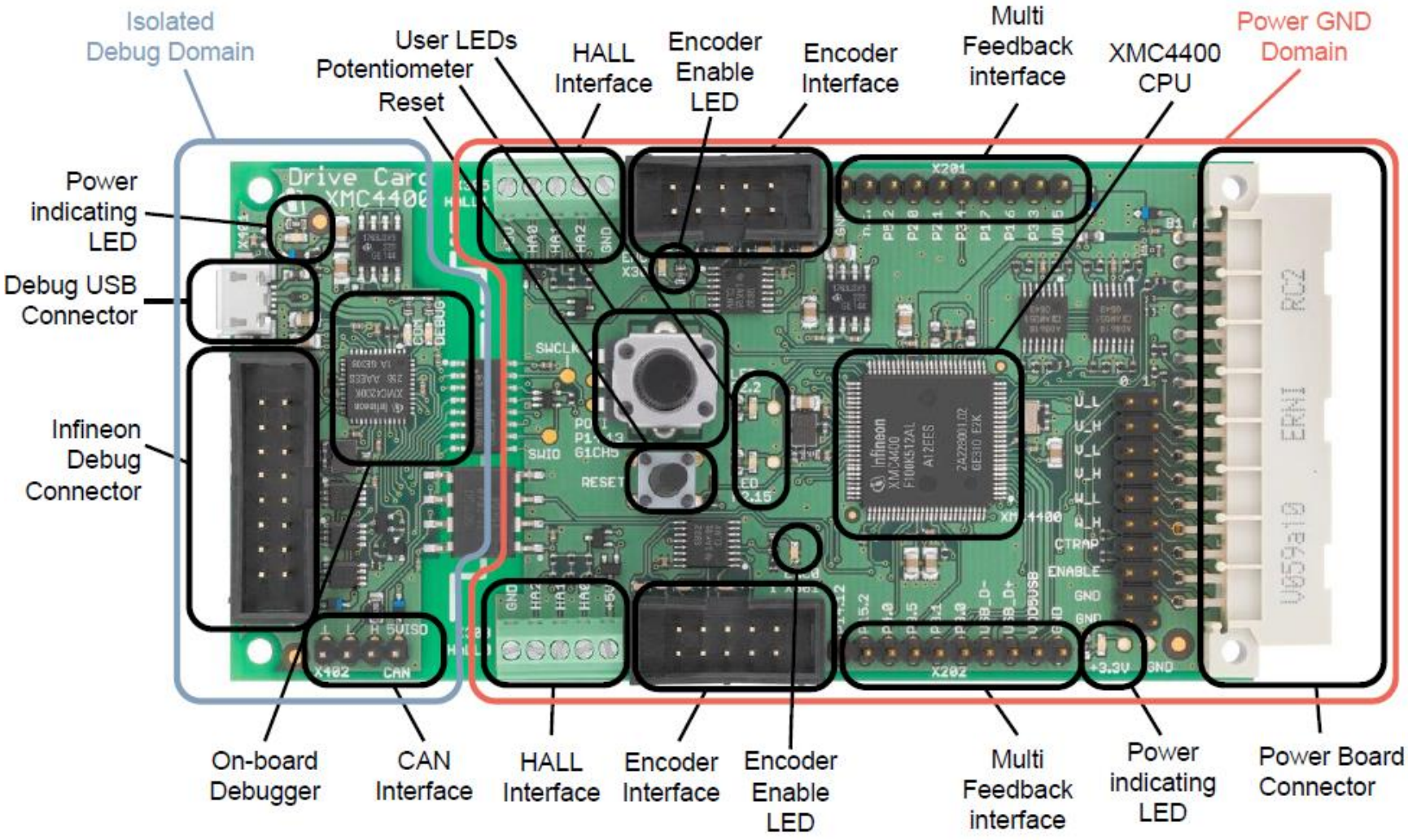
Kit Overview (2/3)

- XMC4400 Drive Card with galvanic isolation



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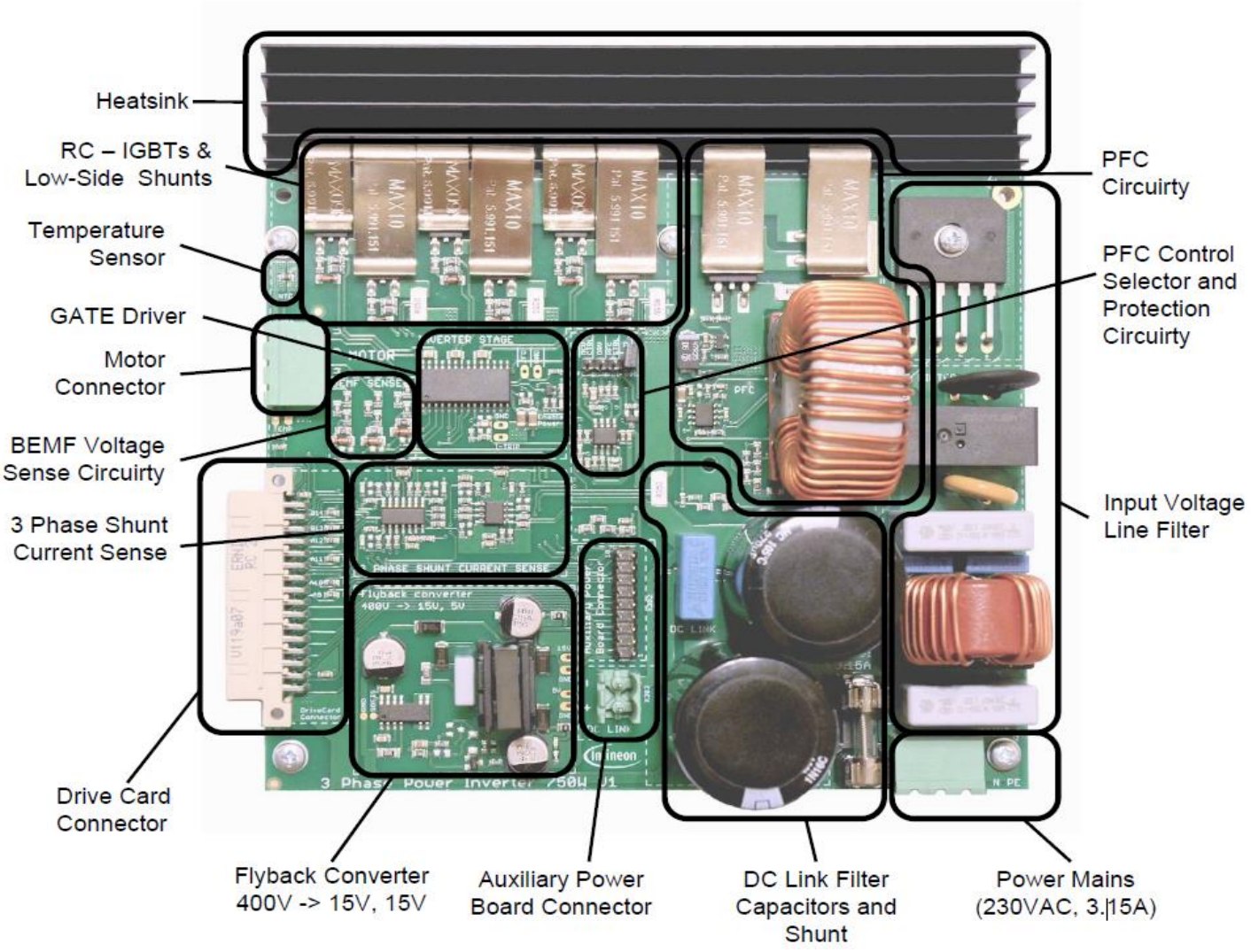
Kit Overview (3/3)

- 3 Phase Power Inverter 750W



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Tooling Overview – Boot Modes (1/2)

- Boot Modes available
  - UART Bootstrap-Loader Mode
  - User Mode (Halt After Reset)
  - User Mode (Debug) **Default Mode of device on Drive Card**
  - User Mode (Productive)

- Boot Modes can be configured via:
  - DAVE
    - Download DAVE

    http://www.infineon.com/DAVE
  - MemTool
    - Download MemTool

    http://www.infineon.com/cms/en/product/channel.html?channel=ff80808112ab681d0112ab6b50fe07c9

- For more information on how to configure the BMI value, please refer to the XMC1000 Tooling Guide.

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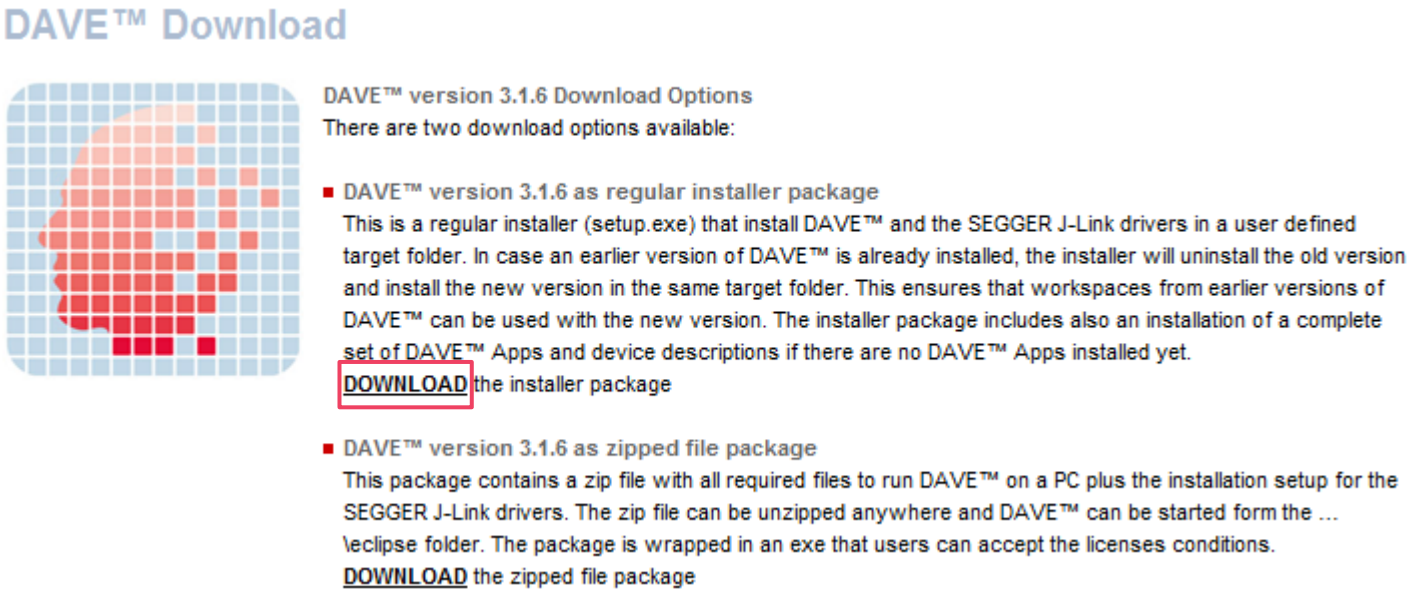
Tooling Overview – DAVE™ (2/2)

- Download DAVE™ installer package from:

http://www.infineon.com/cms/en/product/promopages/aim-mc/DAVE_3_Download.html



- Note: For users who have downloaded DAVE™ as a zipped file package, DAVE™ can be started via DAVE-*.exe in the eclipse folder.

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Getting Started

- Following these steps to get started with XMC 750 Watt Motor Control Application Kit:
  1. Read through **Board Users Manual 3phase Power Inverter 750W**
  2. Connect the power board to a **AC input** power supply
  3. Connect **XMC1300 drive card** to power board
  4. Using the **USB cable** included in the kit with 750W Motor Control Application Kit. The user can **program** the Drive Card to drive the motor after connecting USB cable between a PC & kit

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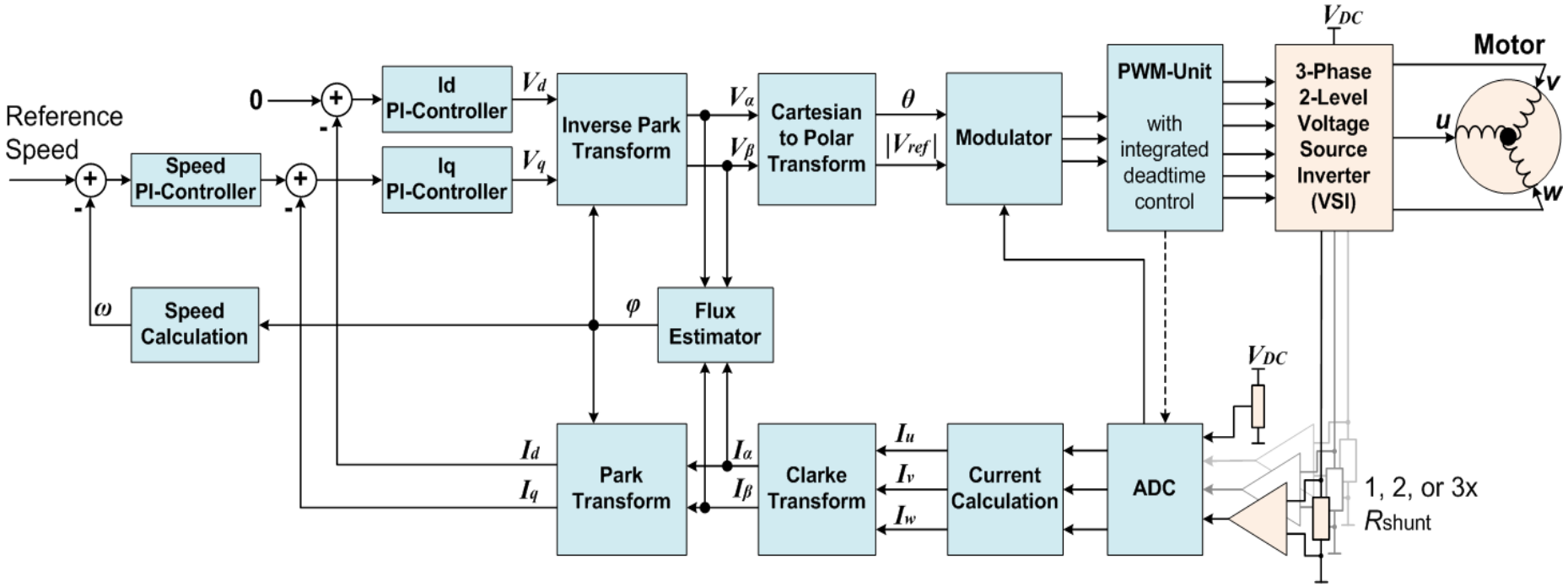
Block Diagram of Infineon Sensorless Field Oriented Control



- In general, FOC is a method to generate a **3-phase sinusoidal signal** which can easily be controlled in frequency and amplitude in order to minimize the current which means to **maximize the efficiency**

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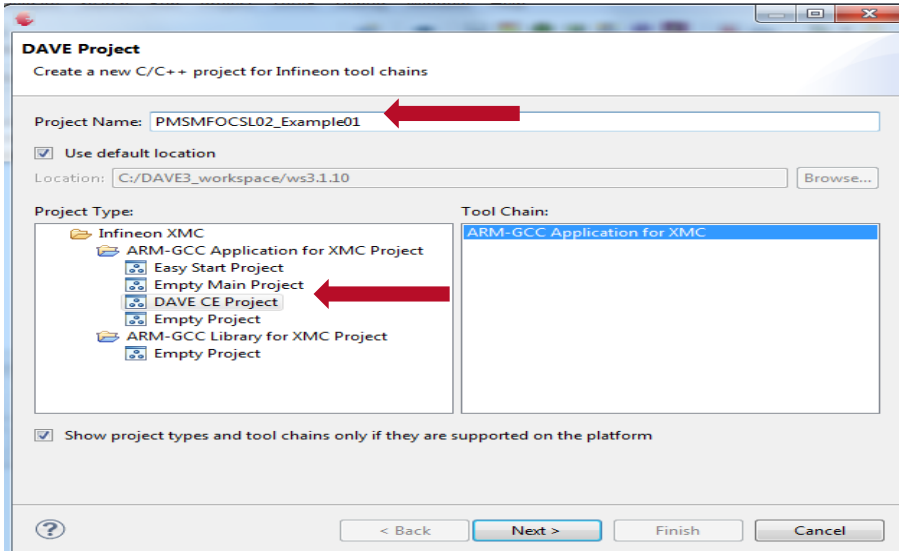
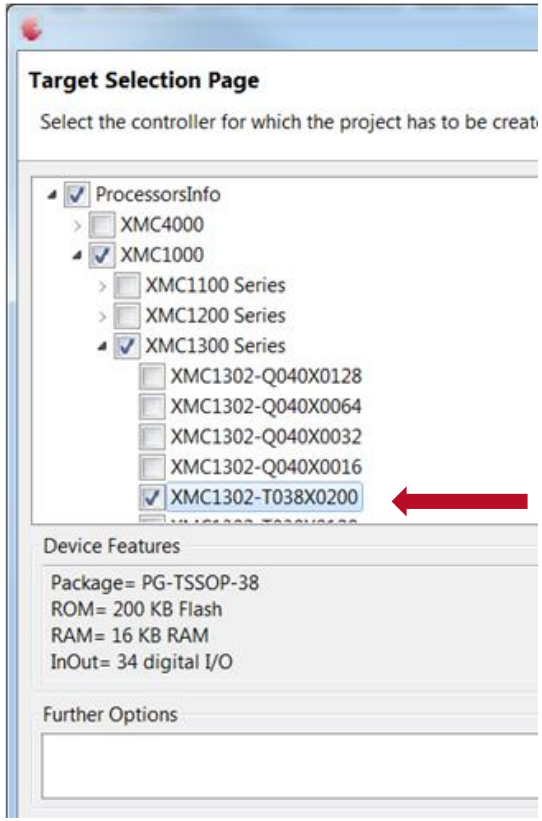
Chapter 1: Generate PMSMFOCSL02 template (1/12)

1. Open DAVE™

2. In DAVE™ workspace, create a new "Empty Main" project:
   - File->New->DAVE Project
   - Give the project a name e.g. "**PMSMFOCSL02_Example01**"
   - Select "DAVE CE Project" as Project Type



3. Select the device accordingly, select "**XMC1300-TO38X0200**" as controller, depending on your hardware



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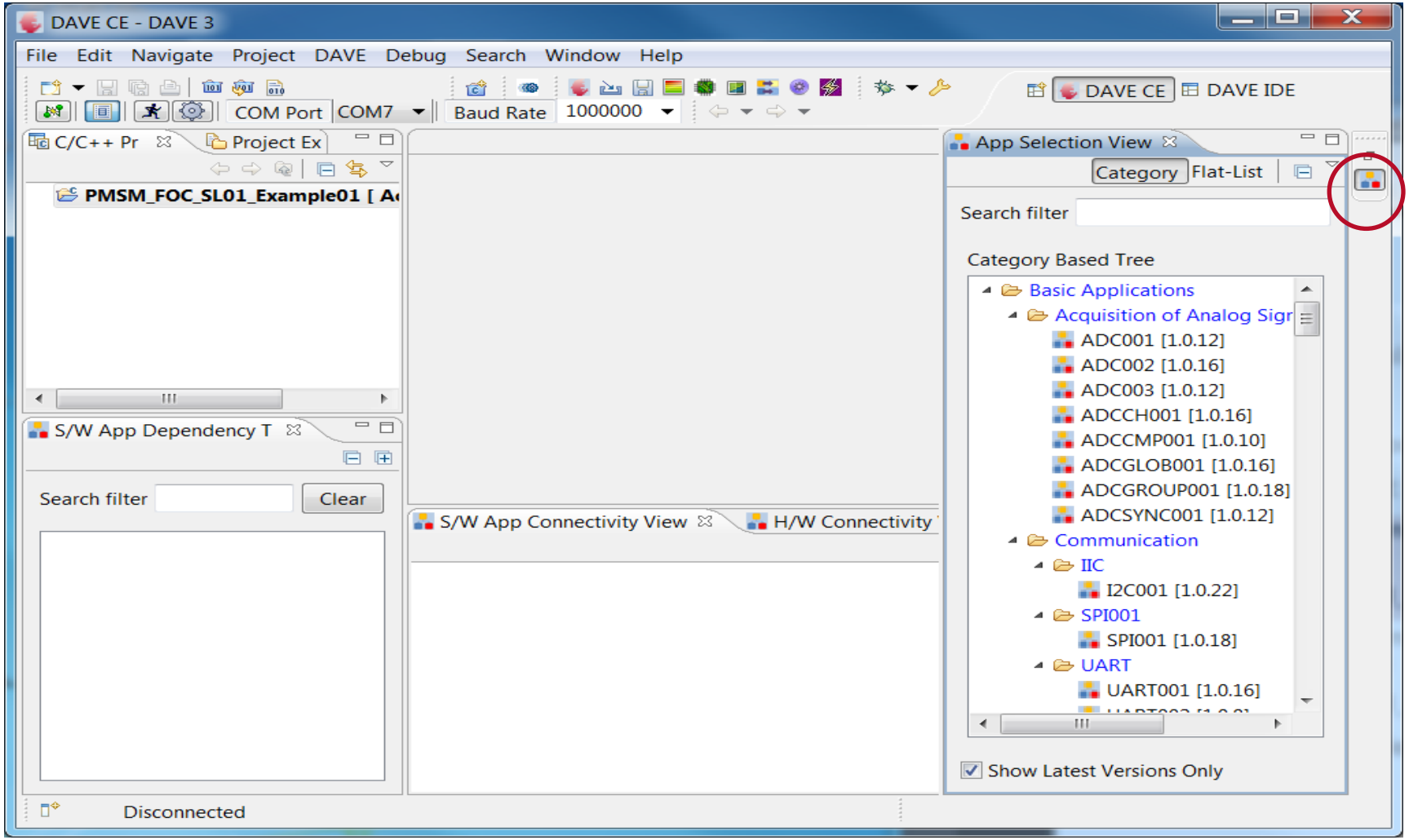
Chapter 1: Generate PMSMFOCSL02 template (2/12)

- Click on “App Selection View” on your right



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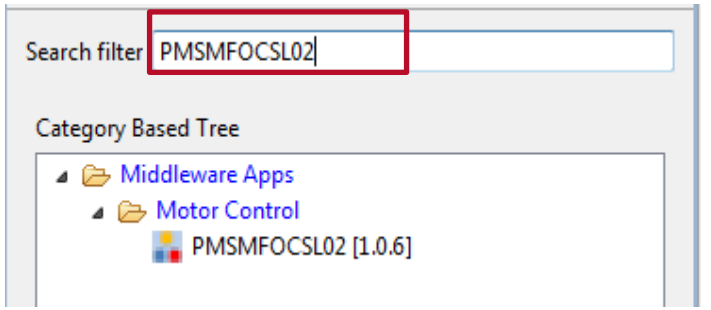
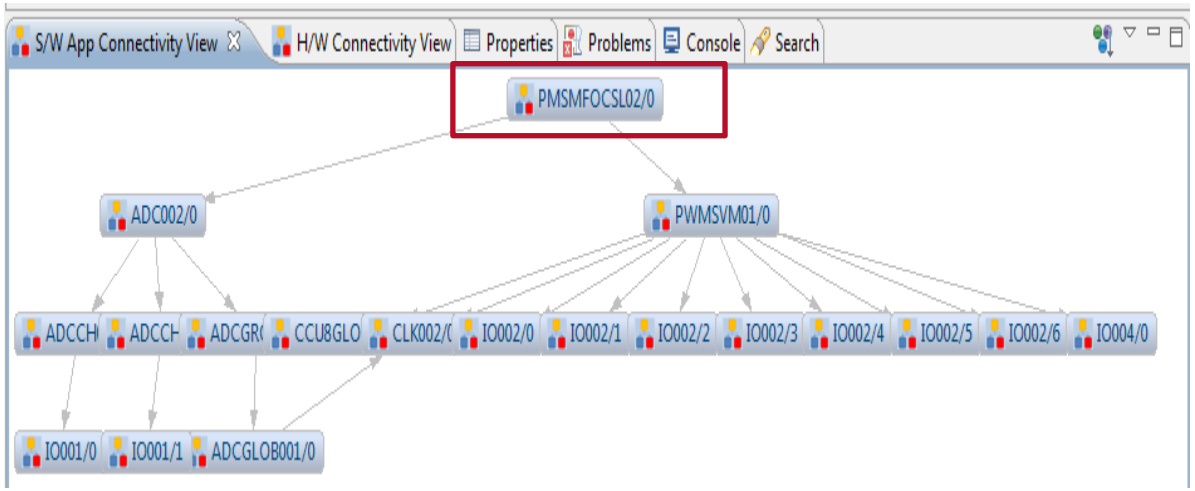
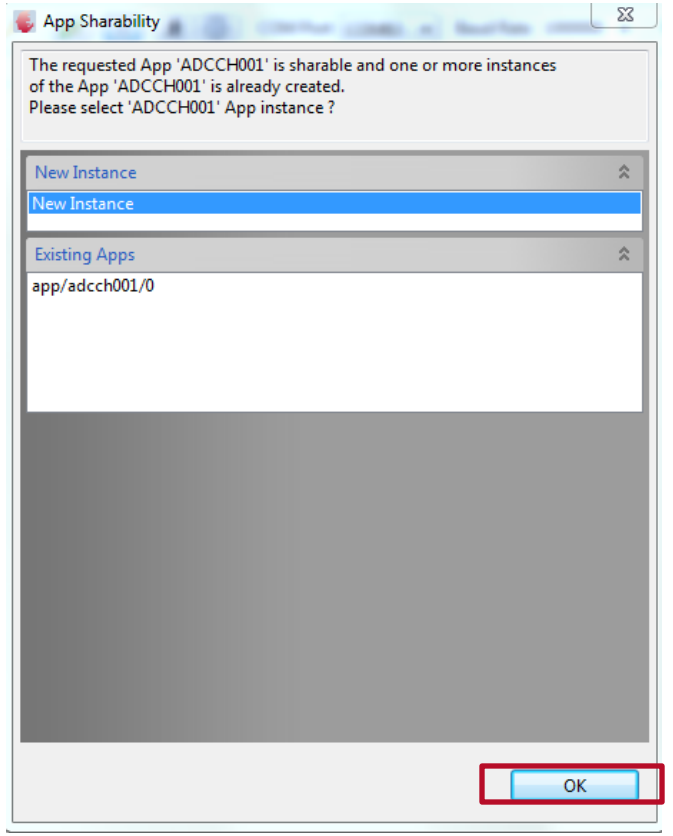
Chapter 1: Generate PMSMFOCSL02 template (3/12)

- Look for "**PMSMFOCSL02**" under App Selection View
- Click "**OK**" to create New Instance for ADC
- Double click on "**PMSMFOCSL02**" in the S/W App Connectivity View







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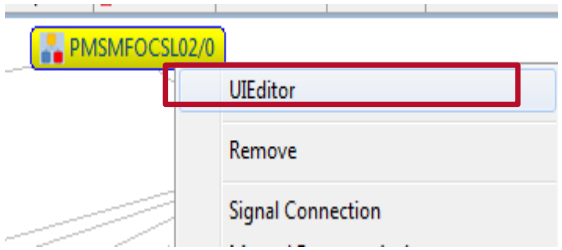
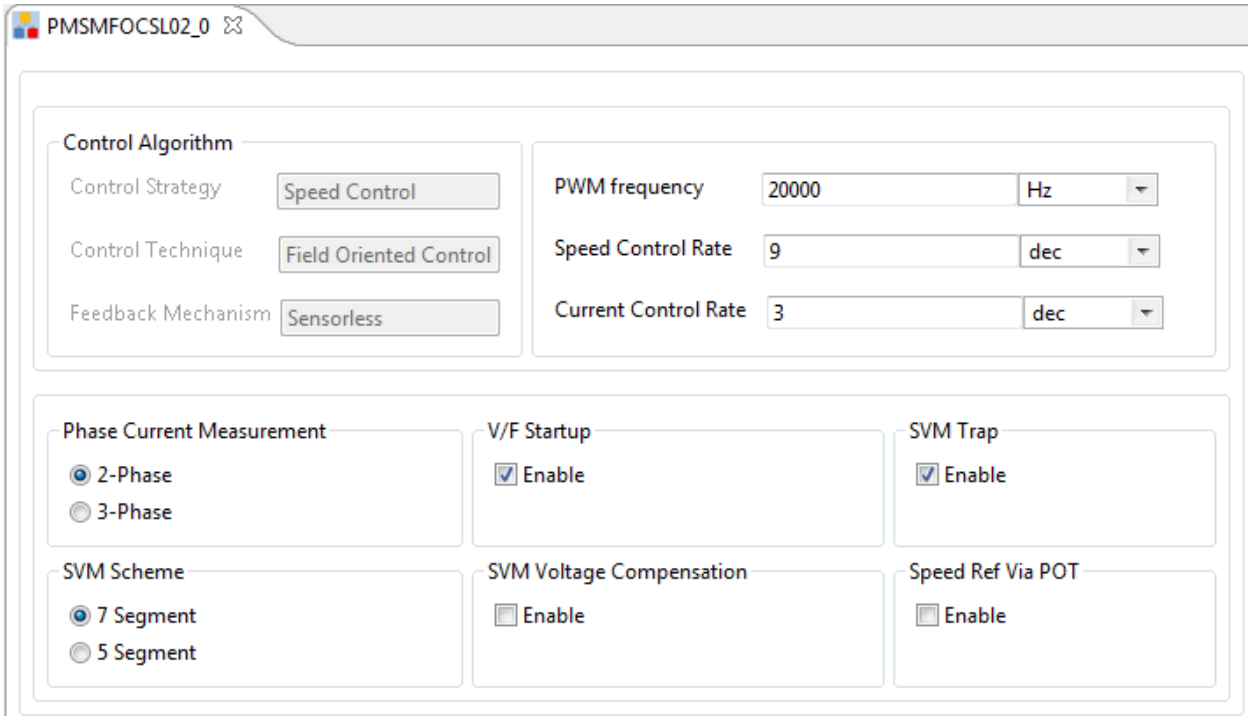
Chapter 1: Generate PMSMFOCSL02 template (4/12)

- Configure PMSMFOCSL02 settings
  - Open **PMSMFOCSL02 UIEditor** by double-clicking or right-click->**UIEditor** on the app in S/W Connectivity View
  - **Control Algorithm** tab,
    - Keep default settings





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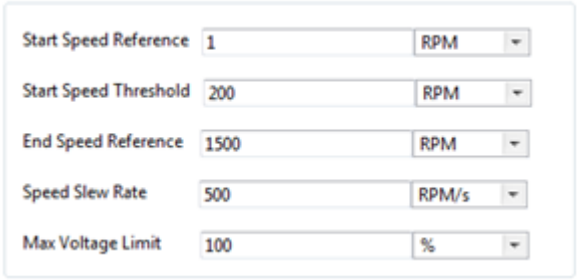
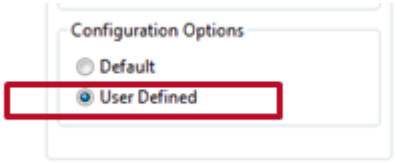
Chapter 1: Generate PMSMFOCSL02 template (5/12)

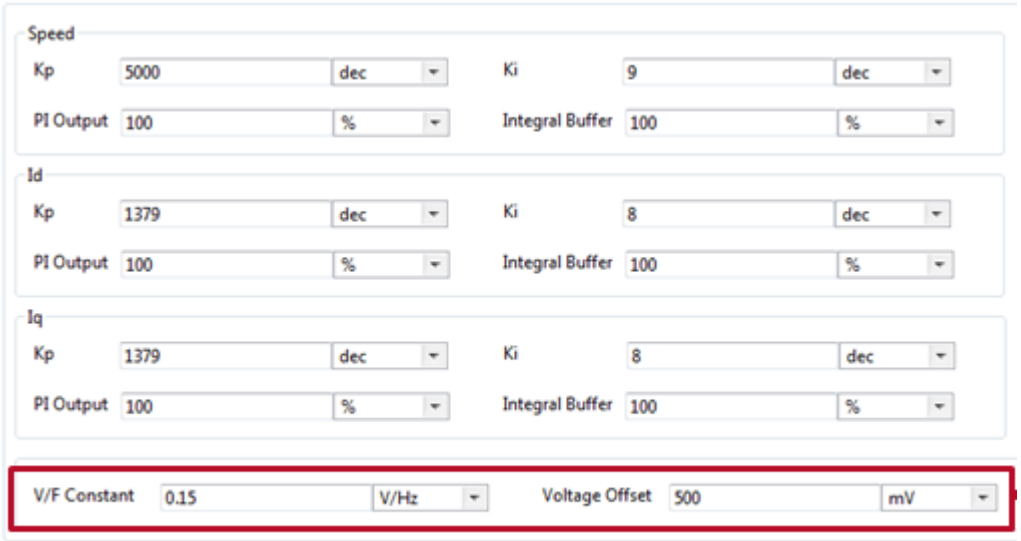
- **Control Panel** tab,



- In PMSMFOCSL02, motor run in open loop (V/F control) and switch to closed loop
- In open loop motor start with **Start Speed Reference** and ramp up the motor until speed reaches as **Start Speed Threshold**
- The control switch to closed loop at **Start Speed Threshold**
- The motor will ramp up until it reaches **End Speed Reference**

- Configuration Options: In Default Mode PI and V/F parameters will be calculated based on motor parameters. Select **User Defined** to fine-tune





- Use For V/F Start-up only

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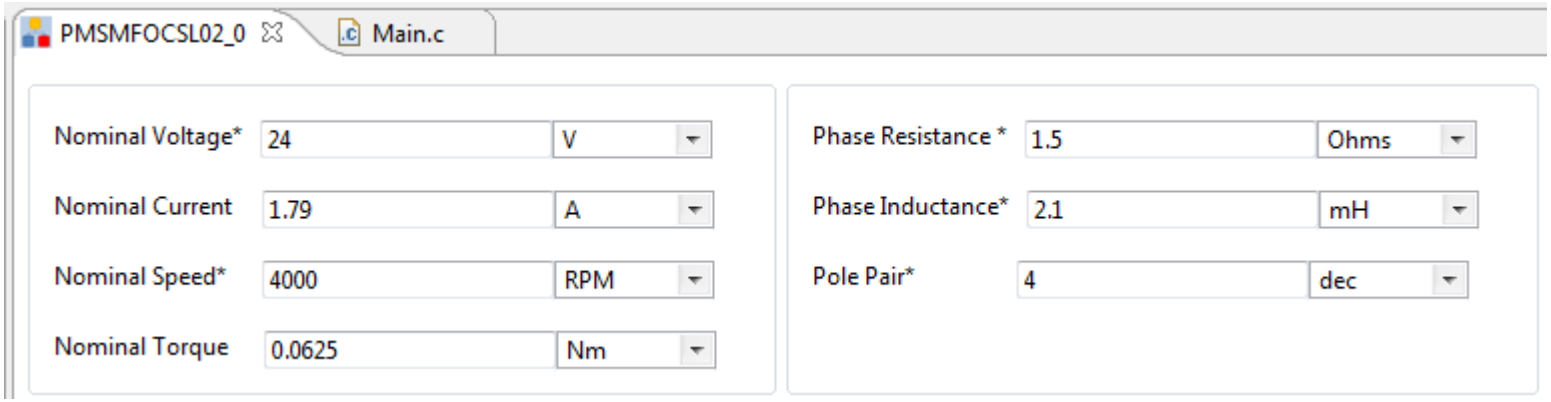
Chapter 1: Generate PMSMFOCSL02 template (6/12)

- **Motor Parameters** tab,
  - Parameters can be found in motor datasheet
  - User can measure motor Phase to Phase **Resistance/Inductance** manually by own measurement devices
  - Refer to Chapter 3 for Motor Electrical Parameter Measurement



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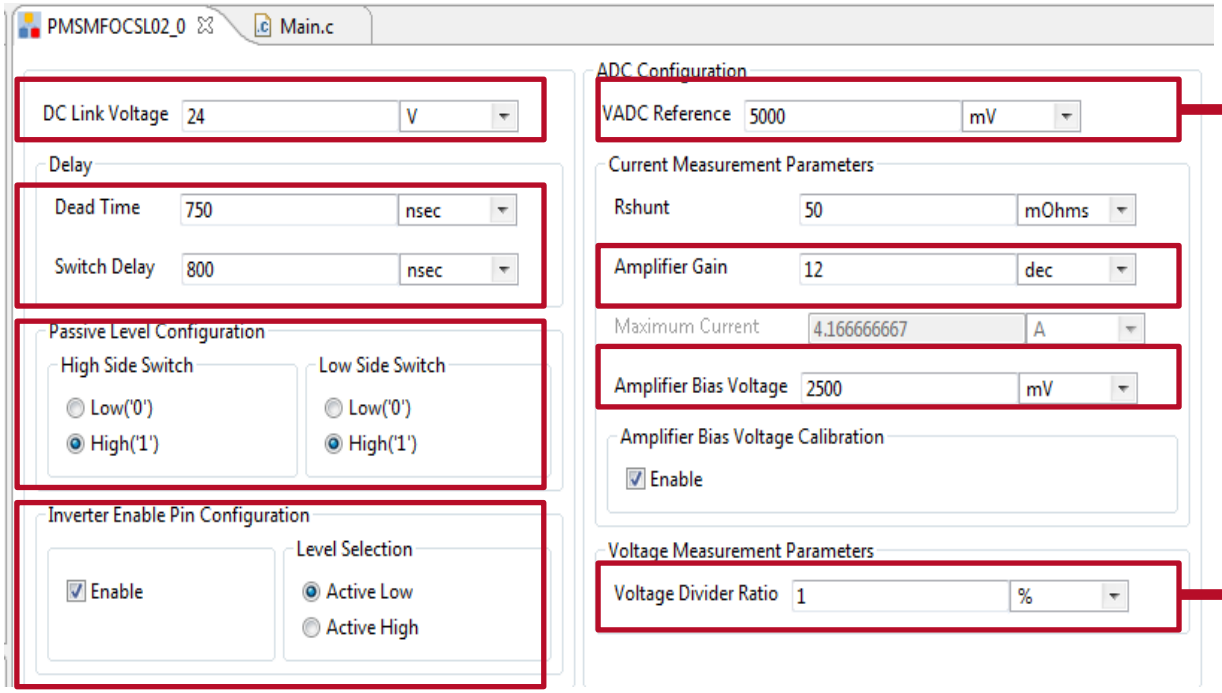
Chapter 1: Generate PMSMFOCSL02 template (7/12)

- **Power Board** tab,
  - **Dead Time** and **Switch Delay** is set to **750ns** and **800ns**.
  - The gate driver (6EDL04I06NT) is negative logic, user need to set **Passive Level Configuration** to **HIGH**.
  - The gate driver **enable signal** is inverted in order to provide **active low**
  - User may refer to **Board Users Manual 750W** to check the power board behavior for more info.



- XMC1300 VADC = 5V
- DC link voltage divider ratio

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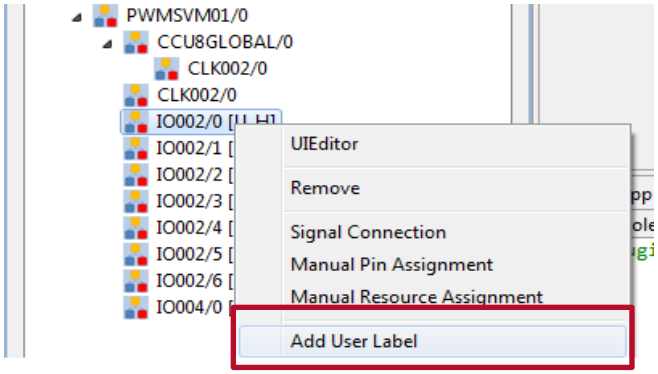
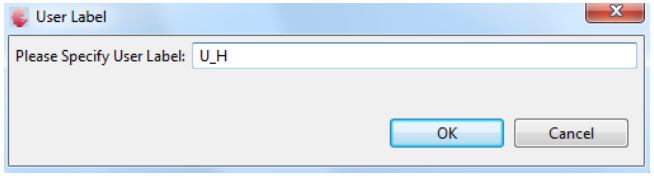
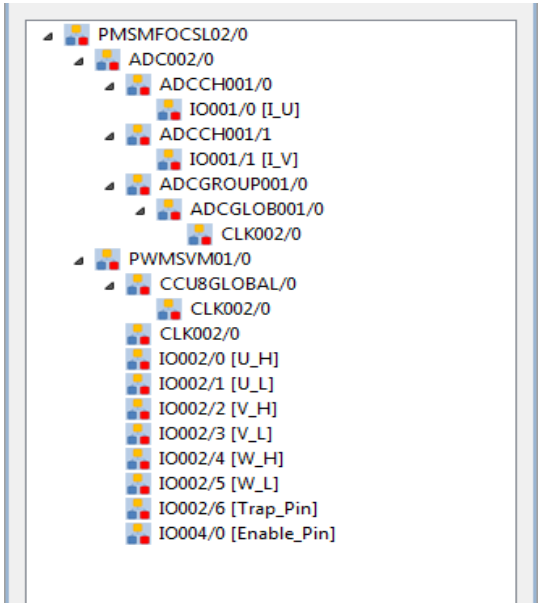
Chapter 1: Generate PMSMFOCSL02 template (8/12)

- Label the apps instance,
  - Under App Dependency TreeView
    - Right click on IO002/0 app -> **Add User Label**
    - Type **U_H** in the field provided
  - Repeat the steps to label other apps







App	Feature
IO002/0 [U_H]	High side Phase U
IO002/1 [U_L]	Low side Phase U
IO002/2 [V_H]	High side Phase V
IO002/3 [V_L]	Low side Phase V
IO002/4 [W_H]	High side Phase W
IO002/5 [W_L]	Low side Phase W
IO004/0 [Enable_Pin]	Enable Pin Gate Driver IC
IO002/6 [Trap_Pin]	Trap Pin
IO001/0 [I_U]	Current Phase U
IO001/1 [I_V]	Current Phase V

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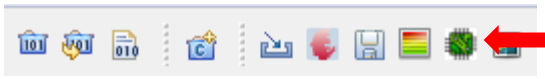
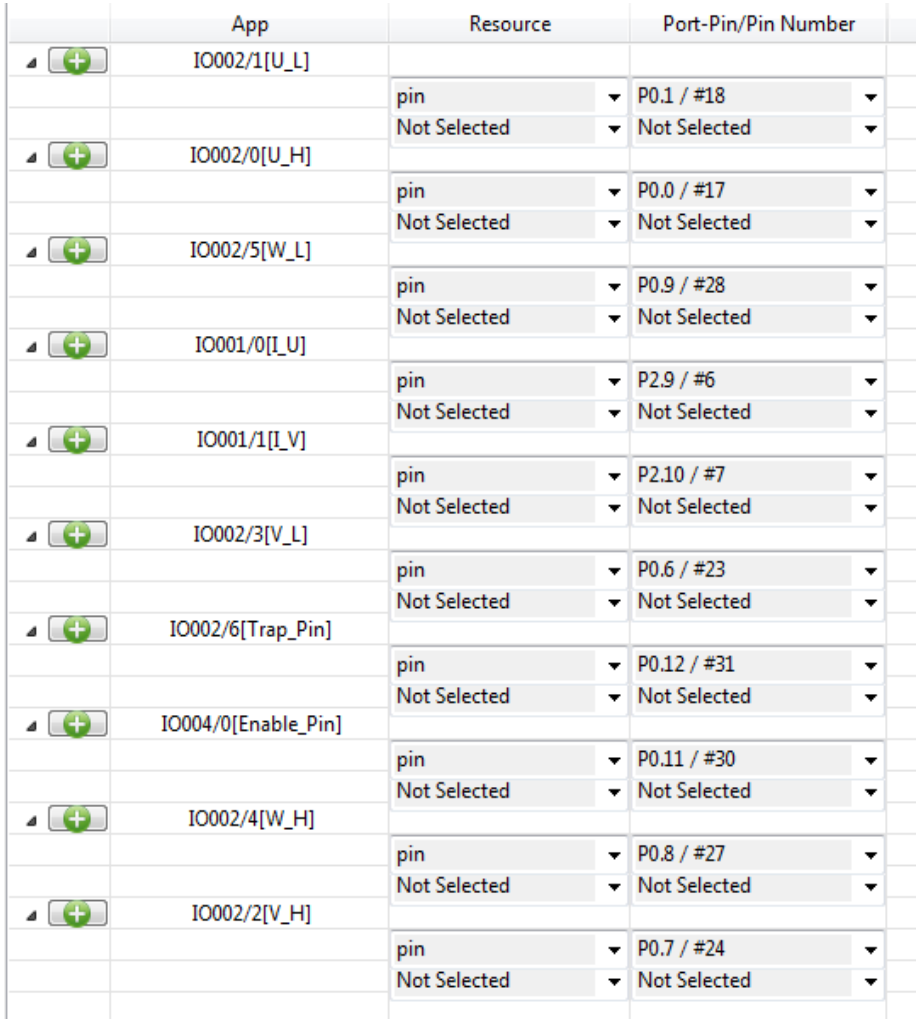
Chapter 1: Generate PMSMFOCSL02 template (9/12)

- Manual Pin Assignment for XMC1300 Drive Card,
  - Assign Pin
    - Click
    - Assign Pins accordingly
    - **Solve** and **Save**
    - **Close**



App	Pin Number
IO002/0 [U_H]	P0.0
IO002/1 [U_L]	P0.1
IO002/2 [V_H]	P0.7
IO002/3 [V_L]	P0.6
IO002/4 [W_H]	P0.8
IO002/5 [W_L]	P0.9
IO004/0 [Enable_Pin]	P0.11
IO002/6 [Trap_Pin]	P0.12
IO001/0 [I_U]	P2.9
IO001/1 [I_V]	P2.10



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Chapter 1: Generate PMSMFOCSL02 template (10/12)

- To Generate Code, Click
- Start the motor by calling the API function **PMSMFOCSL02_MotorStart(&PMSMFOCSL02_Handle0)** in **Main.c**

```
int main(void)
{
//  status_t status;        // Declaration of return variable for DAVE3 APIs (toggle comment if required)

    DAVE_Init();            // Initialization of DAVE Apps

    PMSMFOCSL02_MotorStart(&PMSMFOCSL02_Handle0);
    while(1)
    {

    }
    return 0;
}
```


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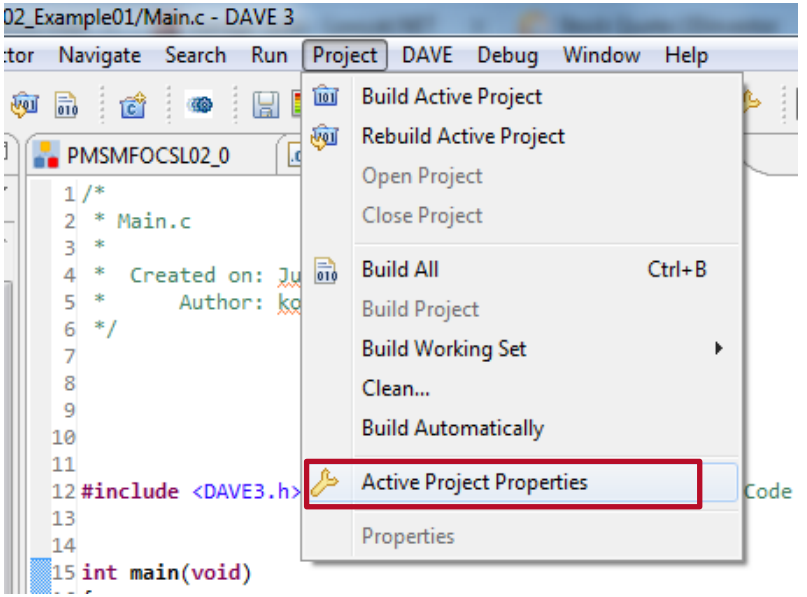
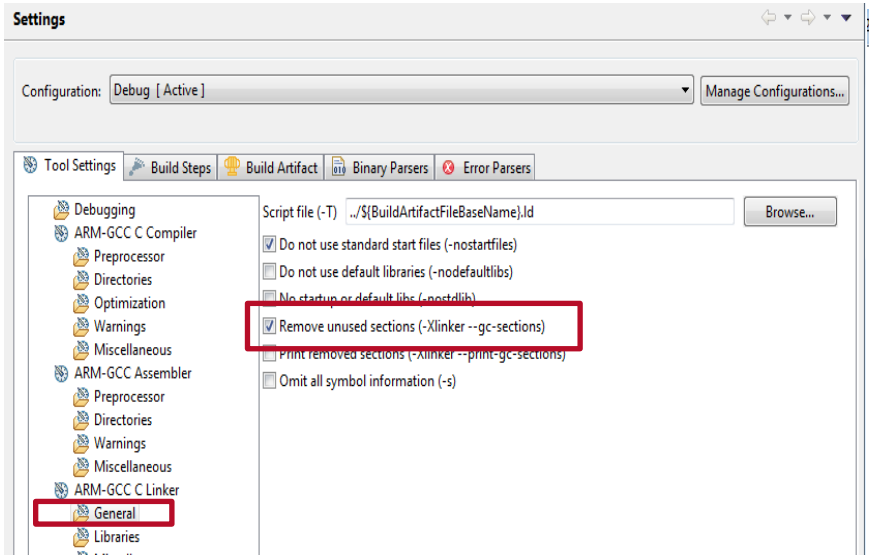
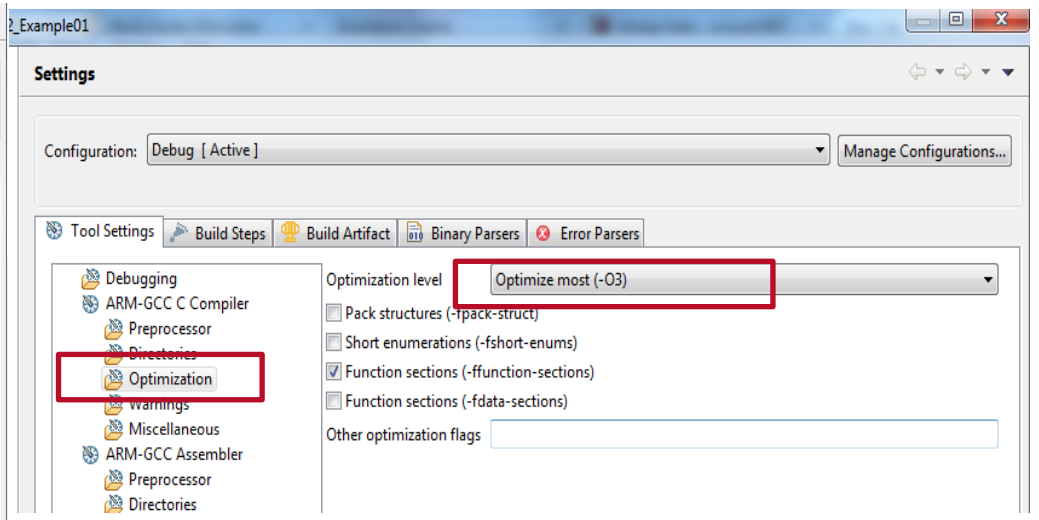
Chapter 1: Generate PMSMFOCSL02 template (11/12)

- Optimize DAVE generated code:
  1. Go to **Project** -> **Active Project Properties**
  2. Under **ARM-GCC C Compiler** -> **Optimization** – **Optimize most (-O3)**
  3. Under **ARM-GCC Linker** -> **General** -> enable **Remove unused section**







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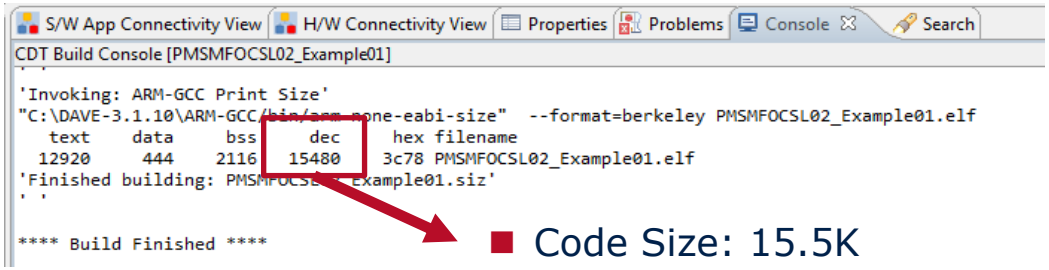
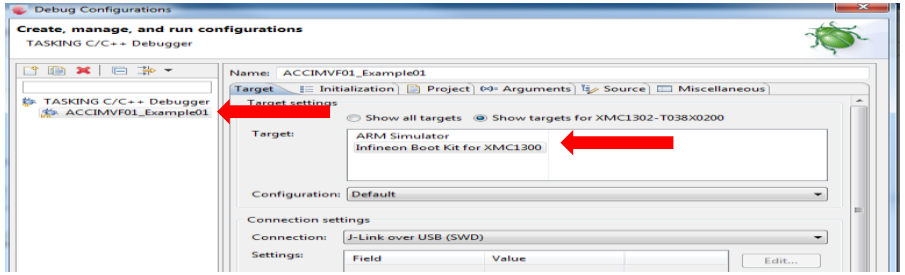
Chapter 1: Generate PMSMFOCSL02 template (12/12)

- Build project
  1. Click
  2. Wait for Build to finish



- Code Size: 15.5K



- Download code
  1. Click
  2. First time download, double **Tasking C/C++ Debugger** in **Debug Configuration**
  3. Select **Infineon Boot Kit for XMC1300** and click **Debug**
  4. Click

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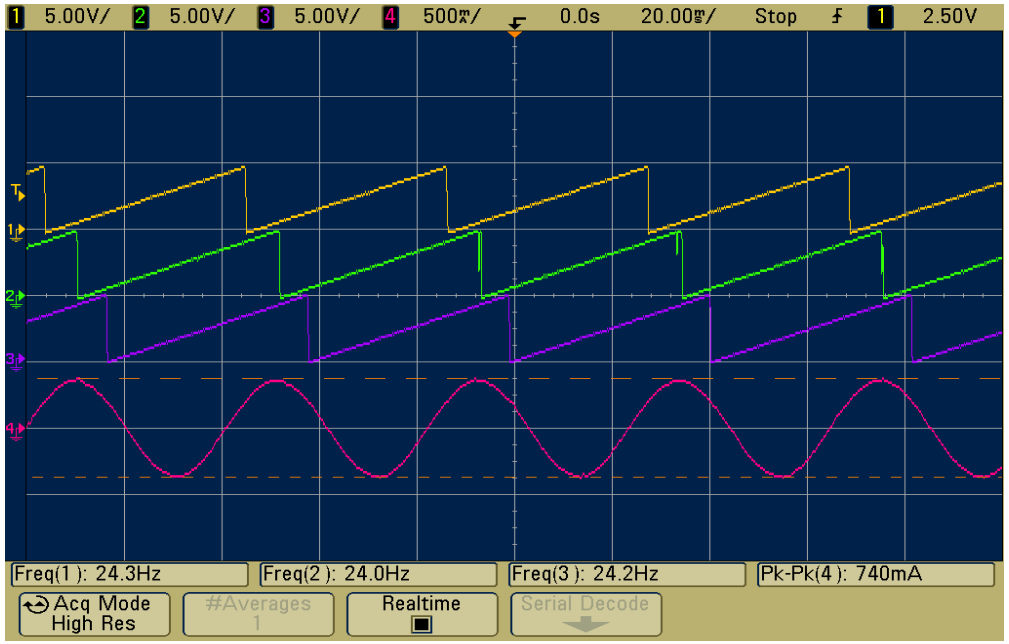
Chapter 2: Configure CCU4 as Debugging feature (1/7)

- The feature enable the user to **visualize** and **analyze** real-time variables, **facilitating** control loop adjustment
  - Function of CCU4_Debug3Output():
    - User can use P0.4, P0.5 and P1.2 on HW board to output variables through **PWM duty cycle** change

1. Set Oscilloscope Acquisition Mode (Press **[Acquire]** key on the front panel) to **"High Resolution"** mode (oscilloscope effectively acts like a low-pass filter) √
2. Or, use **RC filters** to attenuate HF



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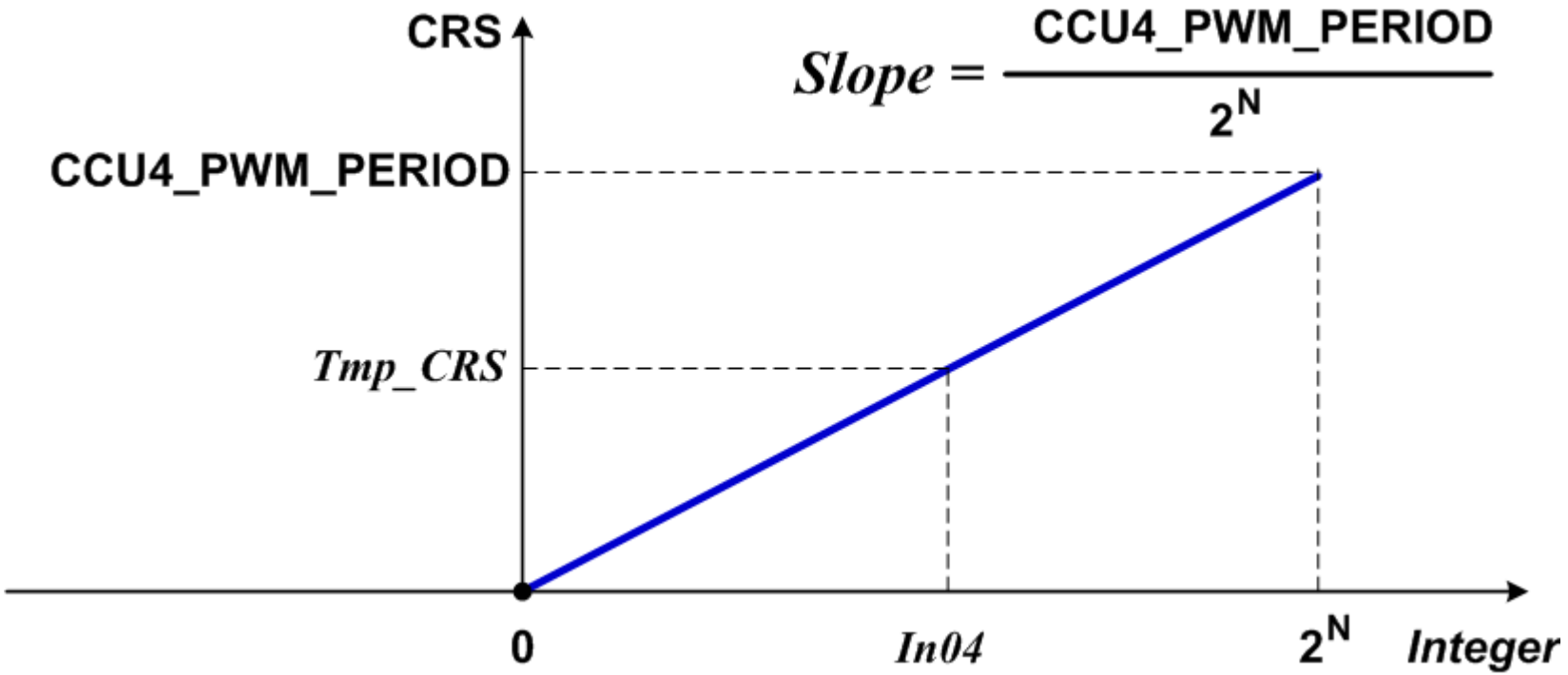
Chapter 2: Configure CCU4 as Debugging feature (2/7)

- User may **SKIP** the steps if debugging feature is not required
- In04 is positive integer



$$Tmp_CRS = \frac{In04}{2^N} * CCU4_PWM_PERIOD$$

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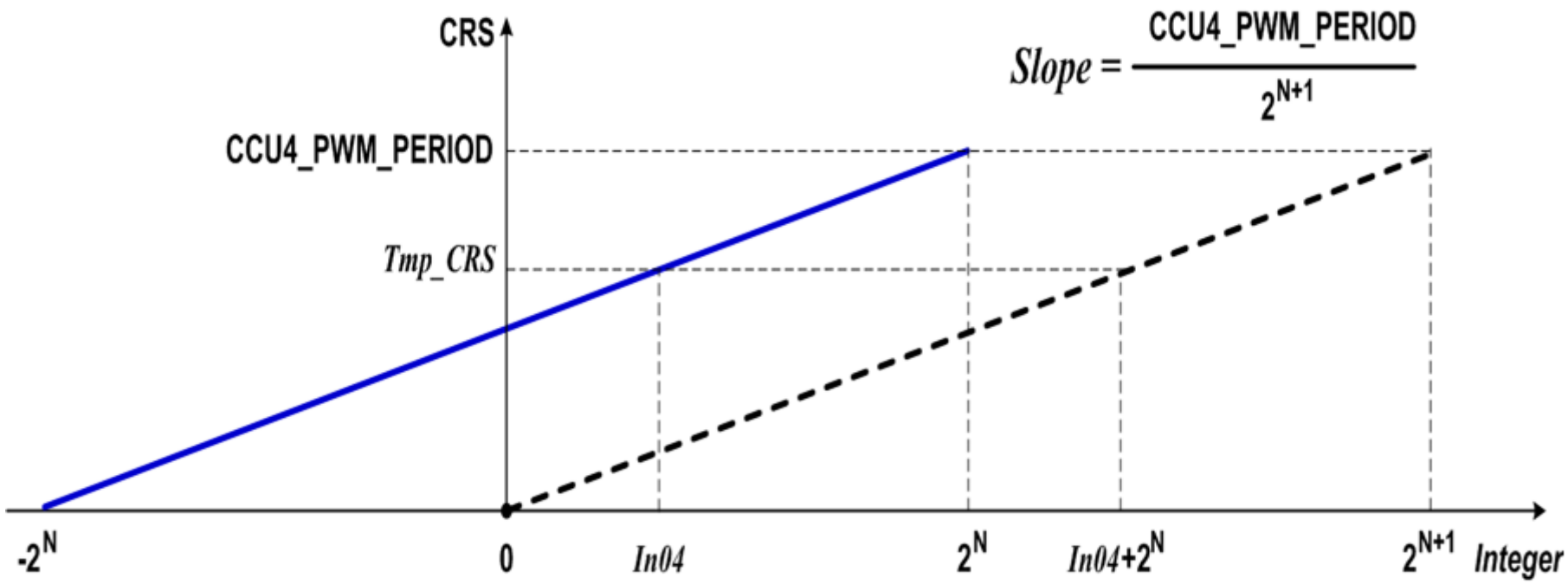
Chapter 2: Configure CCU4 as Debugging feature (3/7)

- In04 is either positive or negative integer



$$\text{Tmp_CRS} = \frac{In04}{2^{N+1}} * \text{CCU4_PWM_PERIOD}$$

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Chapter 2: Configure CCU4 as Debugging feature (4/7)

```
/*### CCU4 Debug with Three Outputs ####
 *### Outputs P0.4, P1.0 and P1.2, for XMC1302-TSSOP38
    * --------------------------------*/
void CCU4_Debug3Output (int32_t In04, uint16_t In04_Flag, uint16_t In04_N, int32_t In10, uint16_t In10_Flag, uint16_t In10_N, int32_t In12, uint16_t In12_Flag, uint16_t
{
    int32_t Tmp_CRS;                                    // Tmp for CCU4 debug.
          // Update P0.4 CCU4 duty-cycle for debug
              if (In04_Flag == 0) {
                  Tmp_CRS = (In04 * CCU4_PWM_PERIOD) >> In04_N;
              }
              else {
                  Tmp_CRS = ((In04 + (1 << In04_N)) * CCU4_PWM_PERIOD) >> (In04_N + 1);
              }
              if (Tmp_CRS >= 0) {
                  CCU40_CC41->CRS = Tmp_CRS;
              }
              else {
                  CCU40_CC41->CRS = - Tmp_CRS;
              }
          // Update P1.0 CCU4 duty-cycle for debug
```

$$\text{Tmp_CRS} = \frac{In04}{2^{In04_N}} \times CCU4_PWM_PERIOD$$

$$\text{Tmp_CRS} = \frac{(In04 + 2^{ln04_N})}{2^{N+1}} \times CCU4_PWM_PERIOD$$

Set 1 if sample +ve and –ve signals

```
/*FOC Calculation */
PMSMFOCSL01_FOCCalculation(&PMSMFOCSL01_Handle0);

CCU4_Debug3Output(PMSMFOCSL01_Handle0.H_Ptr->Ialpha , 1, 9, PMSMFOCSL01_Handle0.H_Ptr->Ia, 1, 9,(uint16_t)PMSMFOCSL01_Handle0.H_Ptr->Angle,0,16);
```

Variable Name

Scale it to 2^9

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Chapter 2: Configure CCU4 as Debugging feature (5/7)

1. Initialize the CCU4 PWM period to 100Khz, 50% duty cycle
2. Configure 3 I/O on board as CCU4 outputs
   - P0.5 – CCU40.OUT0
   - P0.4 – CCU40.OUT1
   - P1.2 – CCU40.OUT2
3. Create software handle function in **Main.c**
4. Call **CCU4_Init()** to initialize CCU4 configuration before start the motor operation
5. Call the **CCU4_Debug3Output()** to sample desire signals in **PMSMFOCSL02_PWMPeriodMatchISR0()**.
   - PMSMFOCSL02_Handle0.H_Ptr->Ialpha
   - PMSMFOCSL02_Handle0.H_Ptr->Ibeta
   - PMSMFOCSL02_Handle0.H_Ptr->Angle

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Chapter 2: Configure CCU4 as Debugging feature (6/7)

1. To avoid DAVE3 **erase user function** when user click **Regenerate code**, please go to:
   - Model -> PMSMFOCSL02 -> 1.0.6 -> Templates -> PMSMFOCSL02c.jet
   - Paste the user function into **PMSMFOCSL02_PWMPeriodMatchISR0()** in **PMSMFOCSL02c.jet**, click **SAVE** and **CLOSE** it.

```
PMSMFOCSL01_ReadCurrent(&PMSMFOCSL01_Handle<%= appInst %>);
/*if CCR is greater than 1, disable  Period Match interrupt*/
<%if(app.getIntegerValue(AppBaseuri + appInst +"/pmsmfocsl01_irwccr") >1){%>
CLR_BIT(PMSMFOCSL01_Handle<%= appInst %>.SVMAppPtr->PhasePtr[0]->INTE, CCU8_CC8_INTE_PME_Pos);
<%}%>
<%if(app.getIntegerValue(AppBaseuri + appInst +"/pmsmfocsl01_erwout0enablepot/0") == 1){%>
  /* Measure the pot value and update the end speed reference value */
PMSMFOCSL01_PotMeasurement(&PMSMFOCSL01_Handle<%= appInst %>);
<%}%>
/*update speed reference value */
PMSMFOCSL01_SpeedRampup(&PMSMFOCSL01_Handle<%= appInst %>);

/*FOC Calculation */
PMSMFOCSL01_FOCCalculation(&PMSMFOCSL01_Handle<%= appInst %>);

CCU4_Debug3Output(PMSMFOCSL01_Handle0.H_Ptr->Ialpha , 1, 9, PMSMFOCSL01_Handle0.H_Ptr->Ia, 1, 9,(uint16_t)PMSMFOCSL01_Handle0.H_Ptr->Angle,0,16);
```

2. Copy the content of **attached main.c,** and paste to user DAVE generated **main.c**

3. **Save** and **close** the **PMSMFOCSL02c.jet**

main.c

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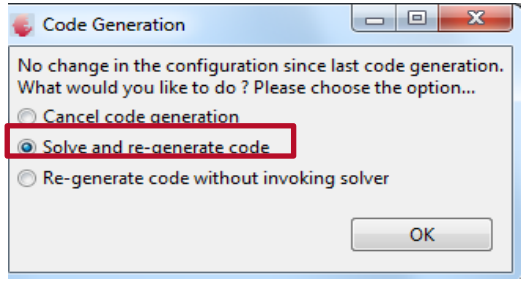
Chapter 2: Configure CCU4 as Debugging feature (7/7)

- Click to regenerate code after modifying *.jet file, with **Solve and re-generate code** then click **OK**
- Now **CCU4Debug3Output()** has been included in **PMSMFOCSL02.c** under **PMSMFOCSL02_PWMPeriodMatchISR0()**




```
/*
 *This is user define interrupt handler for period match interrupt
 */
void PMSMFOCSL02_PWMPeriodMatchISR0(void)
{

  /*Reading Phase-U current*/
  PMSMFOCSL02_Handle0.H_Ptr->Ia =
     (((ADCCH001_HandleType *)PMSMFOCSL02_Handle0.ADCReqSrcPtrA->kChAHandlerPtr)->ADCGrPtr->
         RES[((ADCCH001_HandleType *)PMSMFOCSL02_Handle0.ADCReqSrcPtrA->kChAHandlerPtr)->kStartResultRegNo] & VADC_G_RES_RESULT_Msk);
  PMSMFOCSL02_Handle0.H_Ptr->Ia = -2*(int32_t)((PMSMFOCSL02_Handle0.H_Ptr->Ia)-PMSMFOCSL02_Handle0.H_Ptr->AmpOffset);

  /*Reading Phase-V current*/
  PMSMFOCSL02_Handle0.H_Ptr->Ib =
     (((ADCCH001_HandleType *)PMSMFOCSL02_Handle0.ADCReqSrcPtrB->kChBHandlerPtr)->ADCGrPtr->
         RES[((ADCCH001_HandleType *)PMSMFOCSL02_Handle0.ADCReqSrcPtrB->kChBHandlerPtr)->kStartResultRegNo] & VADC_G_RES_RESULT_Msk);
  PMSMFOCSL02_Handle0.H_Ptr->Ib = -2*(int32_t)((PMSMFOCSL02_Handle0.H_Ptr->Ib)-PMSMFOCSL02_Handle0.H_Ptr->AmpOffset);


  /*if CCR is greater than 1, disable  Period Match interrupt*/
  CLR_BIT(PMSMFOCSL02_Handle0.SVMAppPtr->PhasePtr[0]->INTE, CCU8_CC8_INTE_PME_Pos);
  /*update speed reference value */
  PMSMFOCSL02_SpeedRampup(&PMSMFOCSL02_Handle0);

  /* Calculation of stationary orthogonal reference frame Current Components Ialpha and Ibeta */
  PMSMFOCSL02_Handle0.H_Ptr->Ibeta = MOTORLIBS_ClarkTransform(PMSMFOCSL02_Handle0.H_Ptr->Ia,PMSMFOCSL02_Handle0.H_Ptr->Ib,&(PMSMFOCSL02_Handle0.H_Ptr->Ialpha));
  /*FOC Calculation */
  PMSMFOCSL02_FOCCalculation(&PMSMFOCSL02_Handle0);


  /*call SVM*/
  PWMSVM01_SVM(PMSMFOCSL02_Handle0.SVMAppPtr,
               (uint16_t)PMSMFOCSL02_Handle0.H_Ptr->Amplitude,
               (uint16_t)PMSMFOCSL02_Handle0.H_Ptr->Angle);

  CCU4_Debug3Output(PMSMFOCSL02_Handle0.H_Ptr->Ialpha, 1, 10, PMSMFOCSL02_Handle0.H_Ptr->Ibeta, 1, 10, (uint16_t)PMSMFOCSL02_Handle0.H_Ptr->Angle, 0, 16);
}
```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Agenda (1/2)

- Kit Overview
- Tooling Overview
- Getting Started
  - Chapter 1: Generate PMSMFOCSL02 template
  - Chapter 2: Configure CCU4 as Debugging feature
  - Chapter 3: Motor Electrical Parameters Measurement
  - Chapter 4: Driving Ventilation Fan Application
  - Chapter 5: Driving Ceiling Fan Application

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Chapter 3: Motor Electrical Parameters Measurement (1/4)

- The proposed measurement techniques determine:
  - Number of pole pairs
  - Phase to phase stator resistances, inductances

- The electrical parameters are needed to be configured in DAVE apps to calculate torque, flux PI controller and etc

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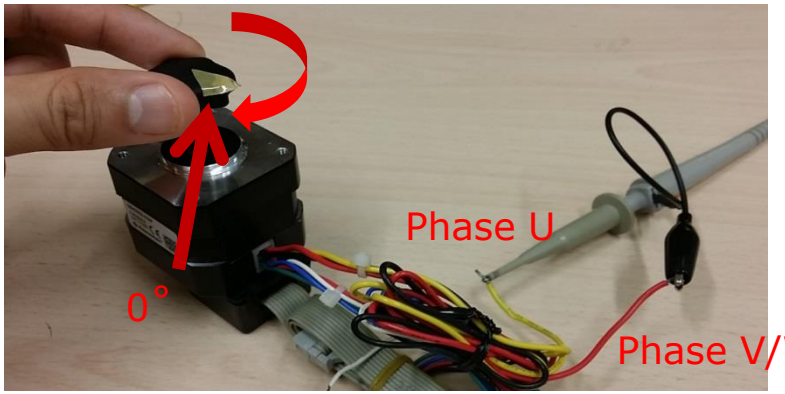
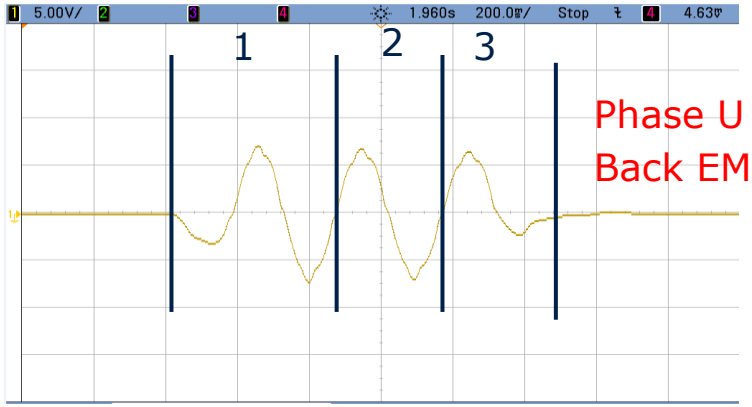
Chapter 3: Motor Electrical Parameters Measurement (2/4)

- Equipments required to measure **motor pole pairs**:
  - Driving motor
  - Oscilloscope, voltage probe
- Following steps describe the method to determine number of motor pole pairs:
  1. Connect the Phase U to signal probe, phase V/Phase W to ground
  2. Rotate the motor manually in 1 mechanical revolution (360°) and capture the waveform in oscilloscope





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Chapter 3: Motor Electrical Parameters Measurement (3/4)

- The number of pole pairs = 3
- The number of pole pairs can be obtained from the motor specification sheet.
- Using measured frequency value, the speed can be calculated using below equation:

$$\text{Speed (RPM)} = \frac{60\ x\ Frequency\ measured\ in\ Hertz}{no.Pole\ Pairs}$$

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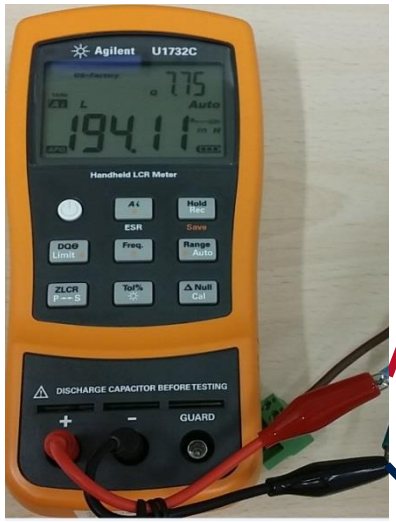
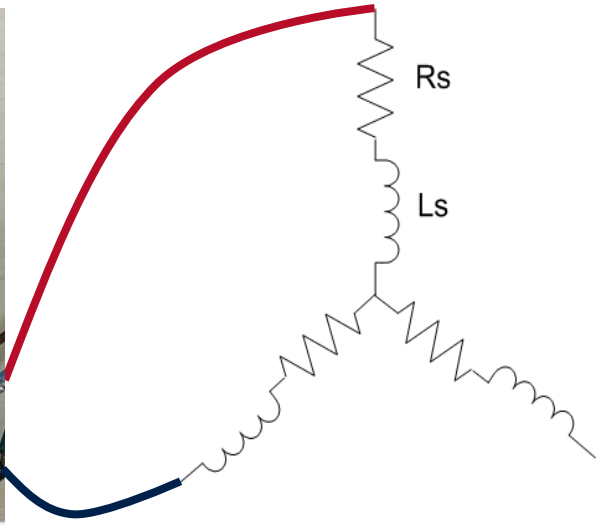
Chapter 3: Motor Electrical Parameters Measurement (4/4)

- Equipment required to measure phase to phase stator resistances and inductances:
  - Digital Multimeter /LCR meter
- Following steps describe the method to measure **phase to phase** resistances and inductances:
  - Phase to Phase Resistance – Use multimeter and measure the DC resistance across the two phase wires of PMSM.
  - Phase to Phase Inductance – Use LCR to measure the inductance at 1Khz across the two phase wires of PMSM





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Agenda (1/2)

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  - Chapter 4: Driving Ventilation Fan Application
  - Chapter 5: Driving Ceiling Fan Application

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Chapter 4: Driving Ventilation Fan Application (1/17)

- Ventilation Fan Application Overview:
  - Microcontroller: Infineon XMC1302-T038X0200
  - Algorithm: Dual Shunt Sensorless FOC (PMSMFOCSL02)
  - Hardware: XMC 750 Watt Motor Control Application Kit (KIT_XMC750WATT_MC_AK_V1)
  - DC Link Voltage: 320 VDC
  - Fan Motor Specification:
    - Phase to Phase Resistance: **19.6 Ω**
    - Phase to Phase Inductance: **154 mH ~ 174 mH**
    - Pole Pairs: **3**
    - Tested Speed range: **500 rpm** to **1000 rpm**

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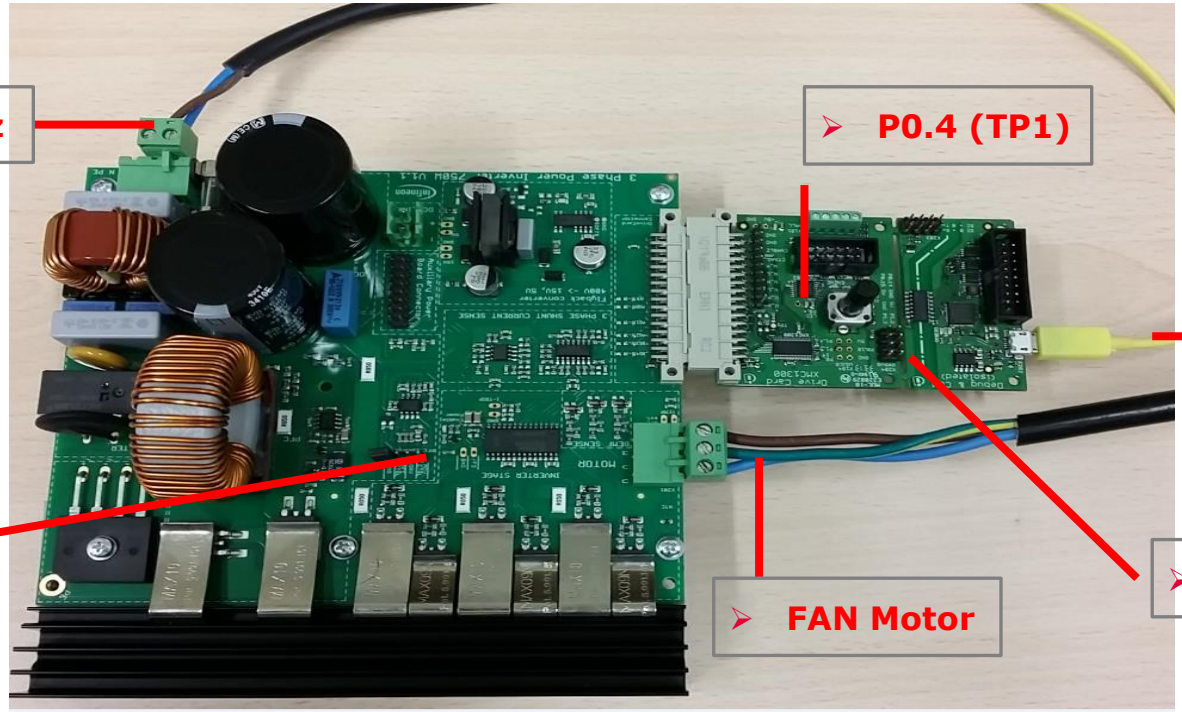
Chapter 4: Driving Ventilation Fan Application (2/17)

- This chapter provides a guideline on how to run ventilation Fan application using PMSMFOCSL02
- TP1, TP2 and TP3 are test points to probe with oscilloscope
- Connect the motor phases to XMC 750 Watt Motor Control Application Kit as shown:



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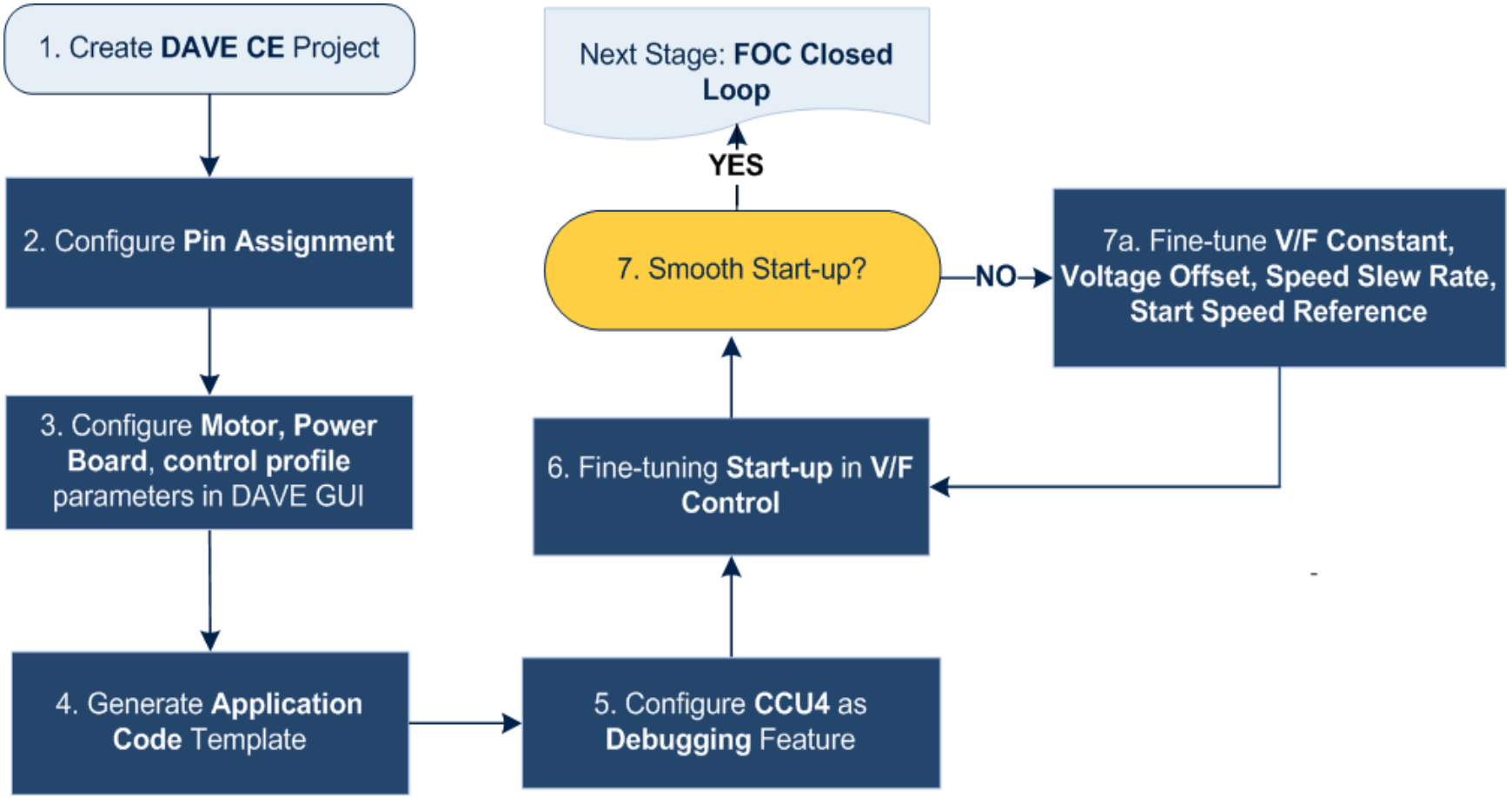
Chapter 4: Driving Ceiling Fan Application (3/17)



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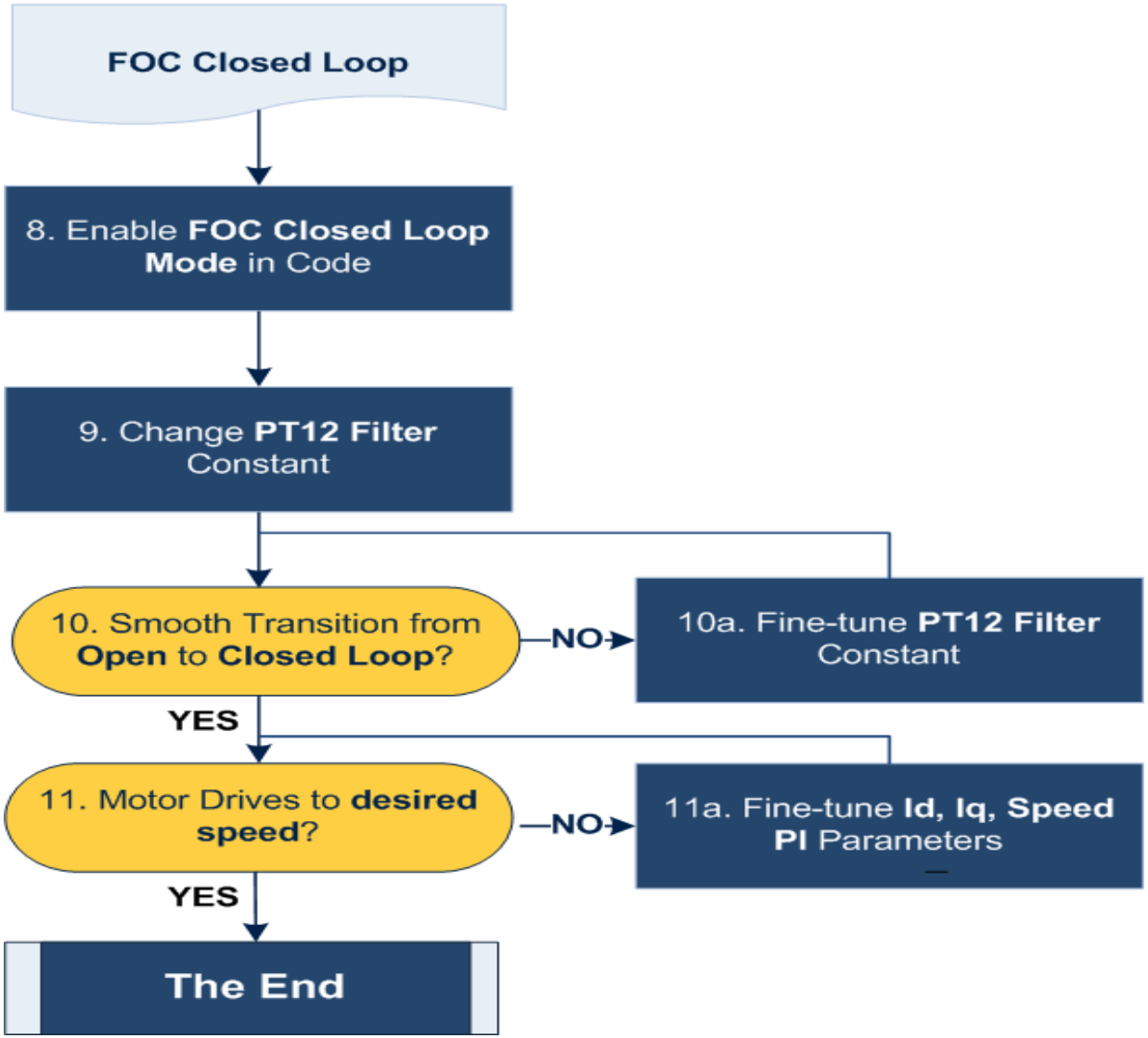
Chapter 4: Driving Ceiling Fan Application (4/17)



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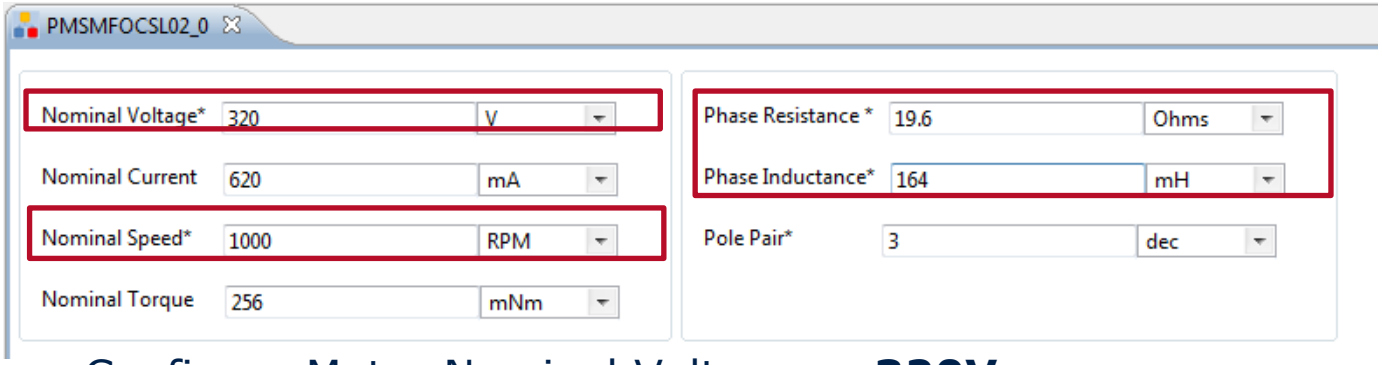
Chapter 4: Driving Ventilation Fan Application (5/17)

1. Create **DAVE CE** project - (page 15)
2. Configure **Pin Assignment** – (page 23)
3. Configure **Motor, power board, control profile parameters** in DAVE GUIs

   - Keep default setting value in **Control Algorithm** tab
   - Click on **Motor Parameters** tab,



   - Configure Motor Nominal Voltage as **320V**
   - Nominal Speed set to **1000 rpm**
   - Phase to phase resistance set to **19.6 Ω**
   - Phase to phase inductance set to **164 mH**
   - Pole Pairs of motor = **3**

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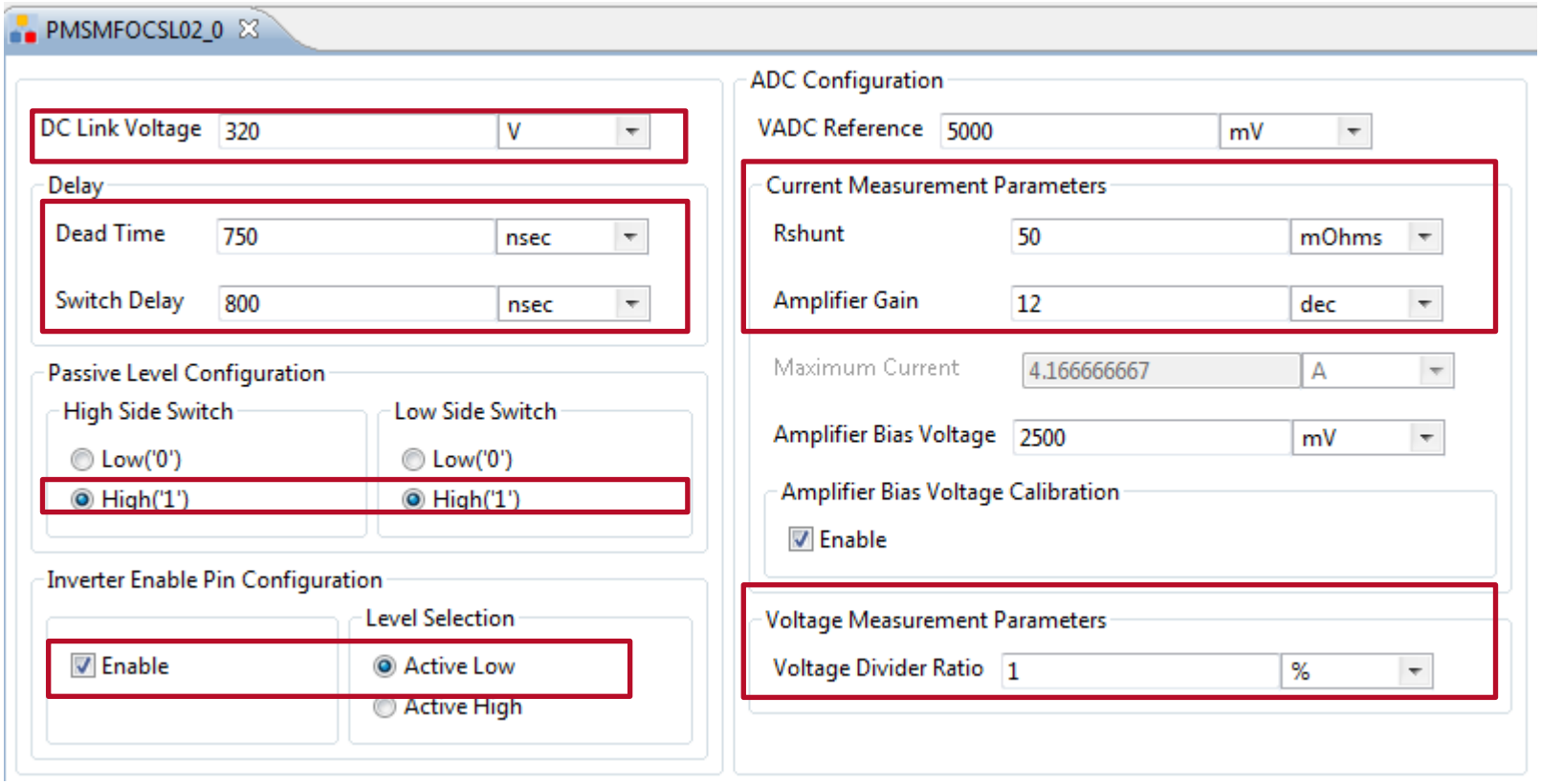
Chapter 4: Driving Ventilation Fan Application (6/17)

- Click on **Power Board** tab,



❖ Refer to page 16 or **750W Board User Manual** for hardware details

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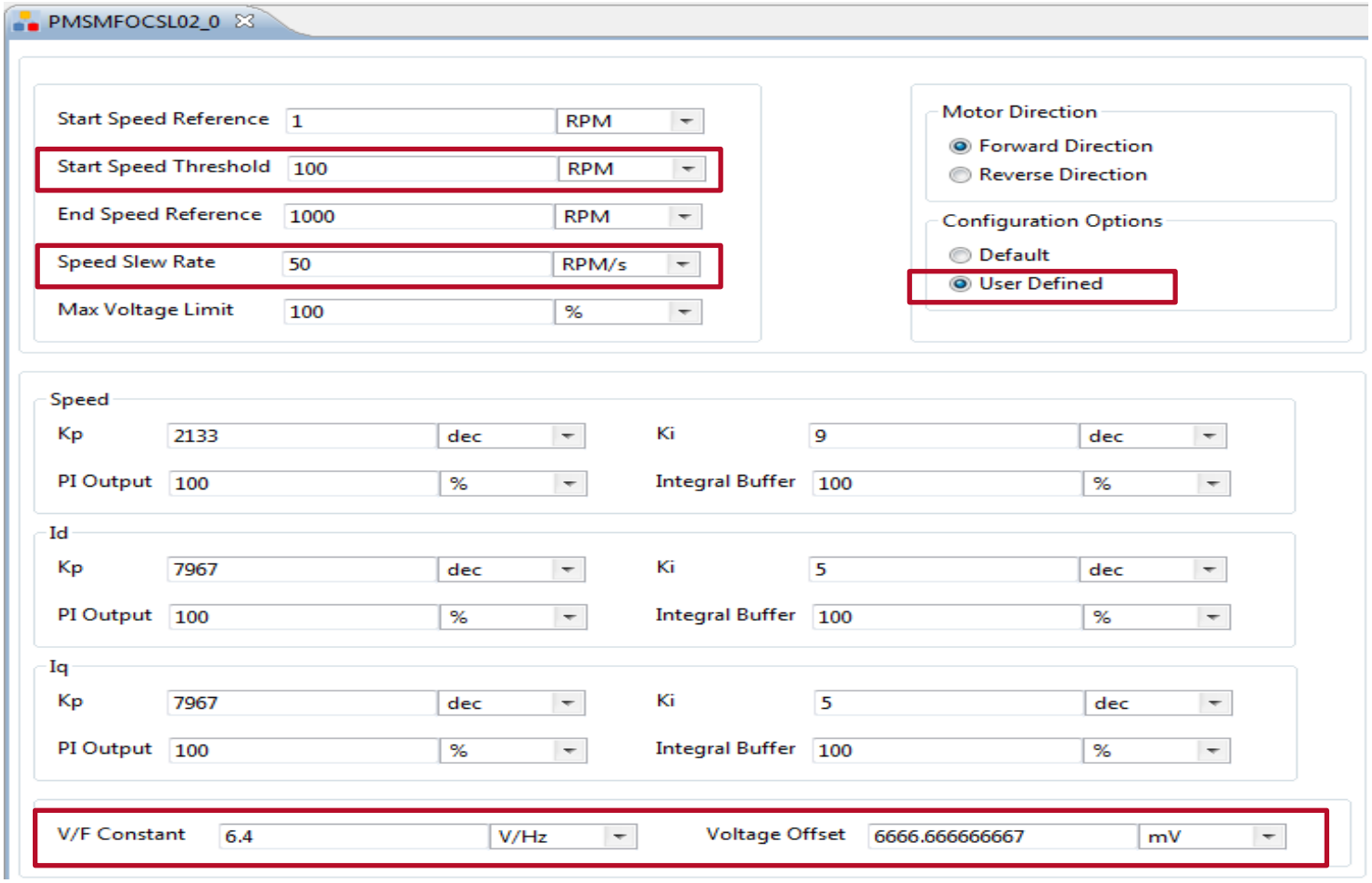
Chapter 4: Driving Ventilation Fan Application (7/17)

- Click on **Control Panel** tab, user should configure start-up parameters for V/F control



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Chapter 4: Driving Ventilation Fan Application (8/17)

4. Generate **Application Code** Template – click
5. Configure CCU4 as Debugging Feature – (page 27 – page 29)
   - Copy the attached **main.c** and paste into user's main.c
6. Fine-tuning Start-up in **V/F control**
   - V/F control principle consist in feeding the motor winding with a 3-phase sinusoidal voltage whose amplitude is proportional to the frequency and time.
   - Under C/C++ projects -> Dave -> Generated -> src -> PMSMFOCSL02.c, search for **PMSMFOCSL02_SpeedRampup()** API function.
   - **Grey out** the 5 code lines as shown:

```
        else
        {
          HandlePtr->H_Ptr->SpeedRef--;
        }
        SET_BIT(HandlePtr->H_Ptr->MotorStatus, PMSMFOCSL02_RAMP_Pos);
      }
      else
      {
//        CLR_BIT(HandlePtr->H_Ptr->MotorStatus,PMSMFOCSL02_OL_Pos);
//        SET_BIT(HandlePtr->H_Ptr->MotorStatus, PMSMFOCSL02_FOC_Pos);
//        HandlePtr->SpeedPI1Ptr->PI1buf = HandlePtr->H_Ptr->SpeedRef<<16;
//        HandlePtr->H_Ptr->State=PMSMFOCSL02_RUNNING;
//        HandlePtr->H_Ptr->SpeedControlRate = (uint32_t)0;
      }
    }
```


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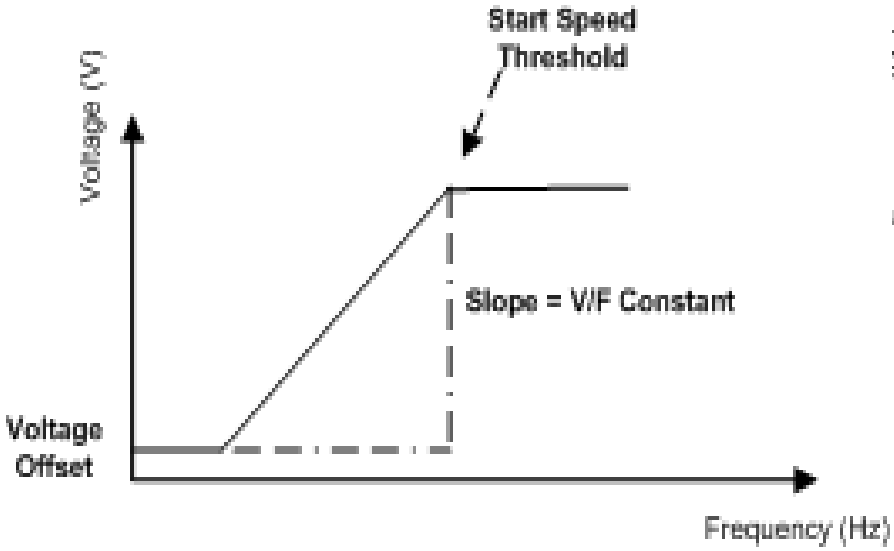
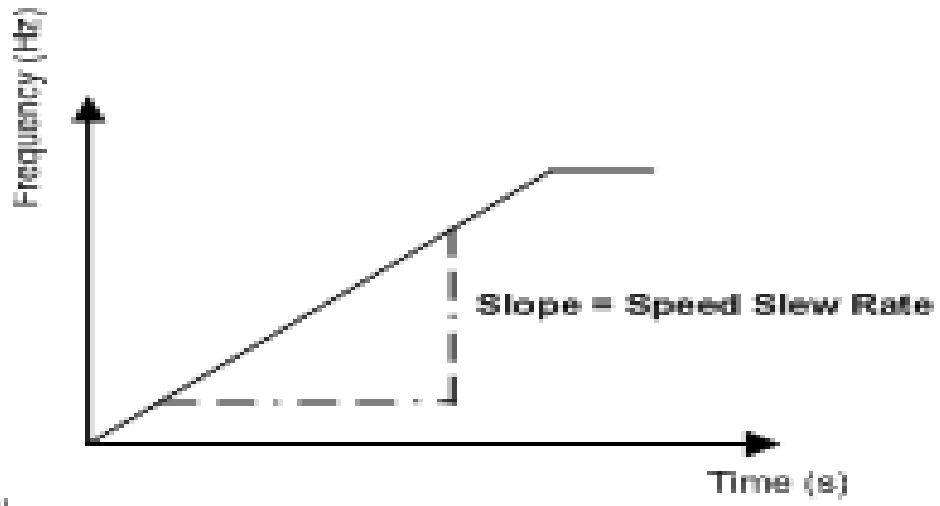
Chapter 4: Driving Ventilation Fan Application (9/17)

- Place 3 signal probes on **P0.4, P0.5, P1.2** on hardware
- Take note that the start-up current would be **HIGH** if user configure motor start-up parameters wrongly. User can always **limit the current** in power supply
- It's recommended to start with **LOW** V/F constant & Voltage Offset. (V/F constant = 1.0 V/Hz, Voltage Offset = 1000 mV)
- The start-up response will be **affected** by Speed Slew Rate, Start Speed Threshold, V/F Constant, Voltage Offset





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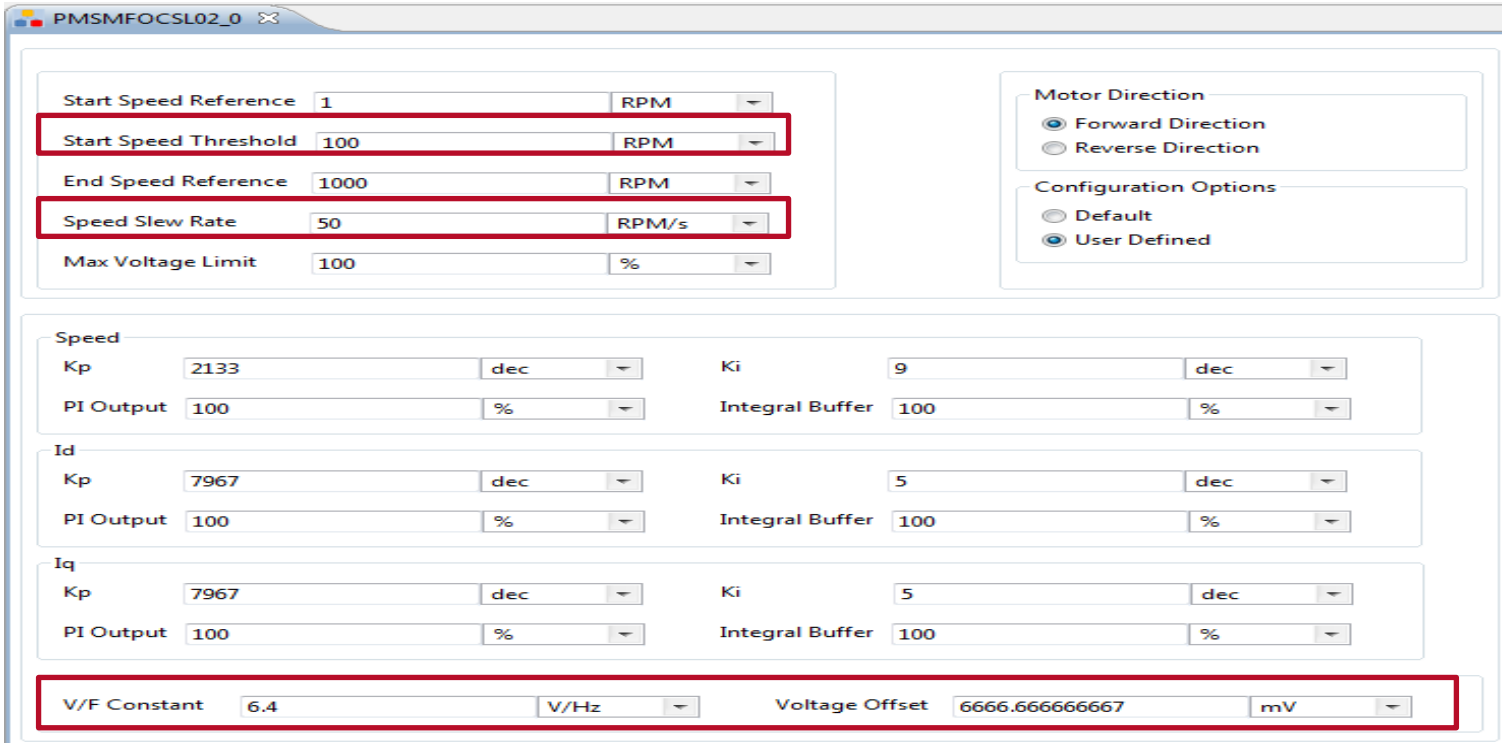
Chapter 4: Driving Ventilation Fan Application (10/17)

7. Evaluate the motor start-up response, repeat fine-tuning steps if necessary.

   - User may reconfigure the **4 parameters** in App GUI, regenerate code is needed for every changes in GUI



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Chapter 4: Driving Ventilation Fan Application (11/17)

- User may change the **RED** highlighted variables to improve the start-up response in PMSMFOCSL02_Config.c

```
PMSMFOCSL02_StartupHandleType PMSMFOCSL02_StartupHandle0 =
{
  .VFOffset  =(uint32_t)249,
  .VFConst   =(uint32_t)3254,
  .Angle     =(int16_t)0
};
```

```
210
211  .kNormSlewRate       =(uint32_t)10172,
212
213  .kAmplitudeMax       =(uint32_t)13329,
214
215  .kAmplitudeMin       =(uint32_t)0,
216
217  .kUserStartSpeedRef  =(int32_t)1,
218  .kUserStartSpeedThreshold  = (int32_t)147,
219
220  .kUserEndSpeedRef    =(int32_t)1474,
221
222  .kSpeedMaxTarget     =(uint32_t)5898,
223
224  .kRampCounter        =(uint32_t)130,
225
226  .kSlewRate           =(uint32_t)60,
227
228  .kSpecifiedVolt      =(uint32_t)2621,
229
```

- The main advantage: Save up compilation time during fine-tuning

- Refer to page 25 to set **code optimization level** in DAVE before user download hex code into XMC1300

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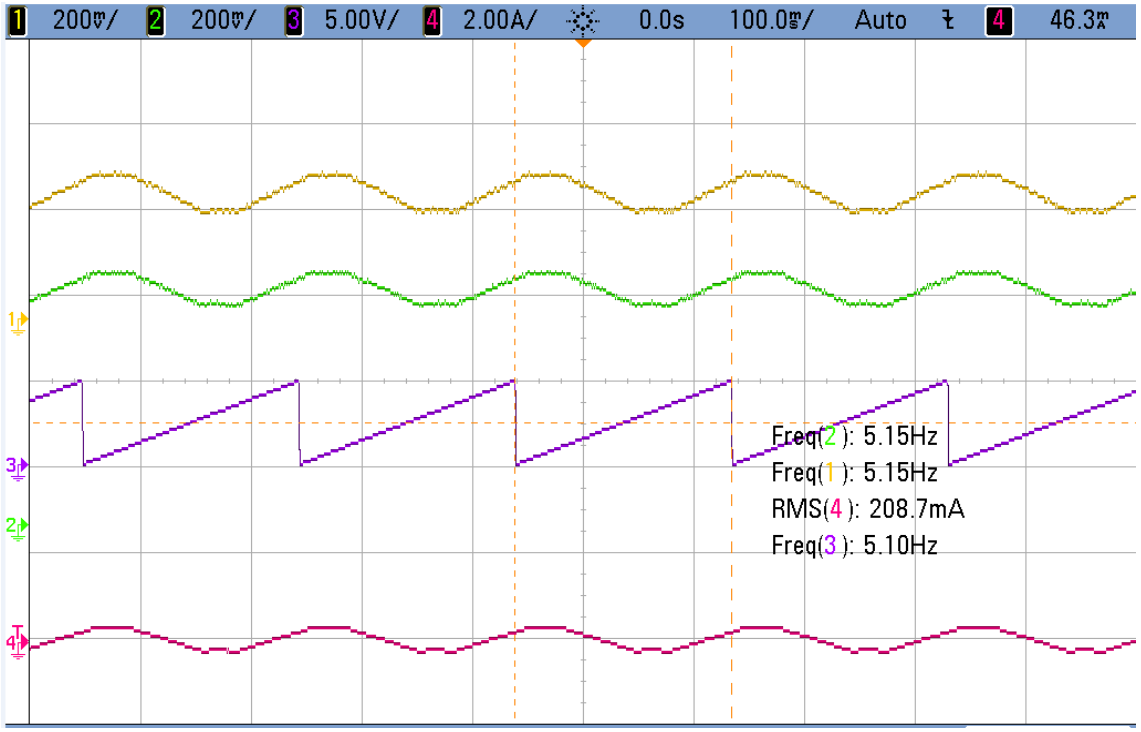
Chapter 4: Driving Ventilation Fan Application (12/17)

- Below shows CCU4 output waveform of Ventilation Fan while running in V/F control Start-up



- Motor Speed = 100 rpm

Channel 1 (yellow):- PMSMFOCSL02_Handle0.H_Ptr-> I_α

Channel 2 (green): - PMSMFOCSL02_Handle0.H_Ptr -> Iu

Channel 3 (blue): - PMSMFOCSL02_Handle0.H_Ptr -> Angle

Channel 4 (pink): Current of fan motor Phase U (measured by current probe, 0.1V/A)

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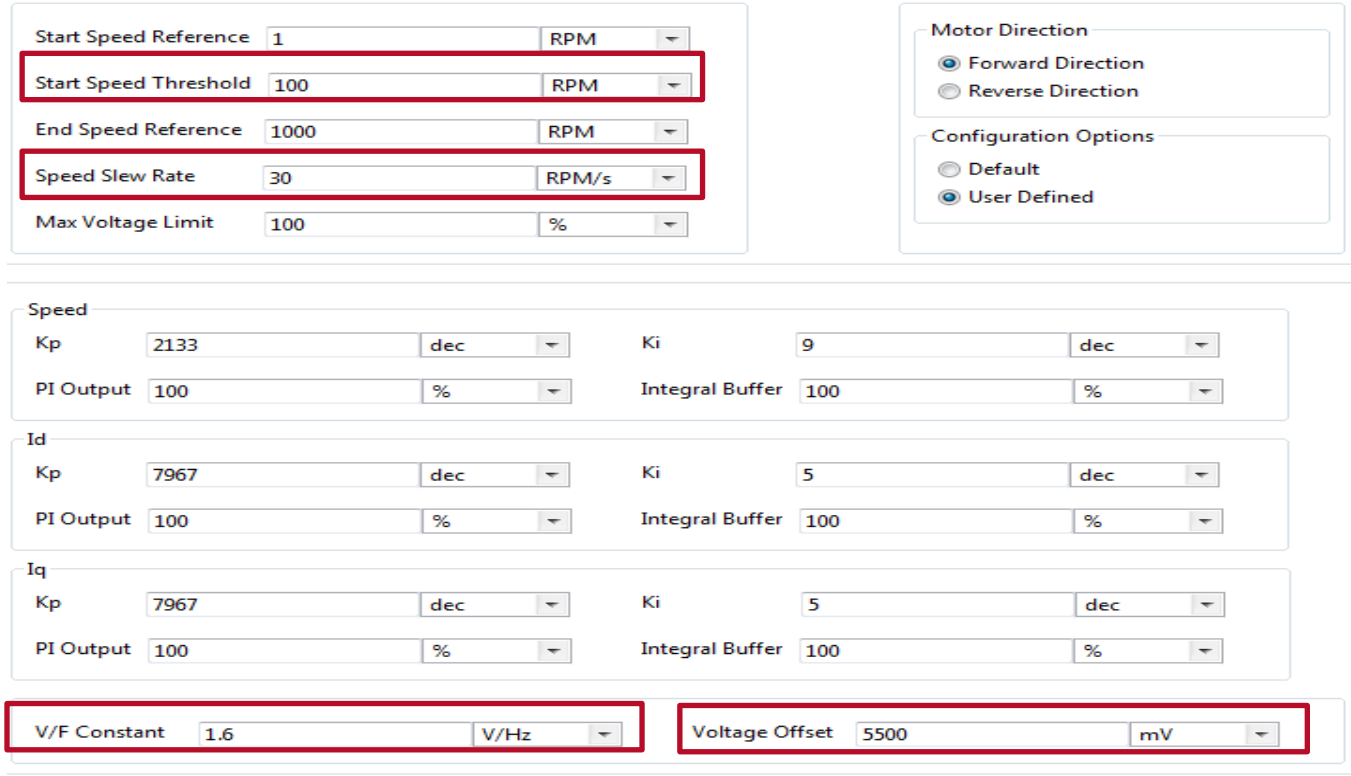
Chapter 4: Driving Ventilation Fan Application (13/17)

- Screenshot of typical **V/F parameters** value in DAVE App



- The Start-up parameters shown are mainly for **references** purpose. Due to differences between various motor, the V/F control parameters needs to be **tuned** to drive every new motor model

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Chapter 4: Driving Ventilation Fan Application (14/17)

8. The **FOC Closed Loop** operation can be **ENABLED** by **uncommenting** the 5 lines highlighted as below:

   - Under C/C++ projects -> Dave -> Generated -> src -> PMSMFOCSL02.c, search for **PMSMFOCSL02_SpeedRampup()** API function.

```
        else
        {
          HandlePtr->H_Ptr->SpeedRef--;
        }
        SET_BIT(HandlePtr->H_Ptr->MotorStatus, PMSMFOCSL02_RAMP_Pos);
      }
      else
      {
//      CLR_BIT(HandlePtr->H_Ptr->MotorStatus,PMSMFOCSL02_OL_Pos);
//      SET_BIT(HandlePtr->H_Ptr->MotorStatus, PMSMFOCSL02_FOC_Pos);
//      HandlePtr->SpeedPI1Ptr->PI1buf = HandlePtr->H_Ptr->SpeedRef<<16;
//      HandlePtr->H_Ptr->State=PMSMFOCSL02_RUNNING;
//      HandlePtr->H_Ptr->SpeedControlRate = (uint32_t)0;
      }
    }
```

- Skip the following page 50 to page 52 if user is using **PMSMFOCSL02[1.0.8]** and above
- **Id** and **Iq KpKI** values in App GUI are calculated based on motor resistance and inductance values. Speed PI Kp and KI are not calculated, it is hardcoded values.

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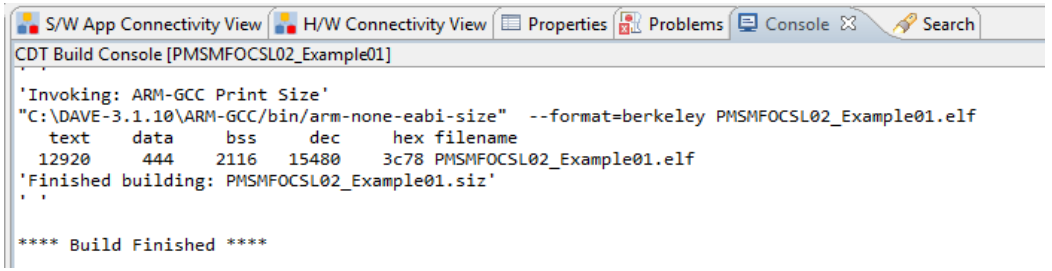
Chapter 4: Driving Ventilation Fan Application (15/17)

- Build project (At this stage, the motor will be driven in FOC Closed Loop mode
  1. Click , Wait for Build to finish



- Download code
  1. Click & click to run the motor

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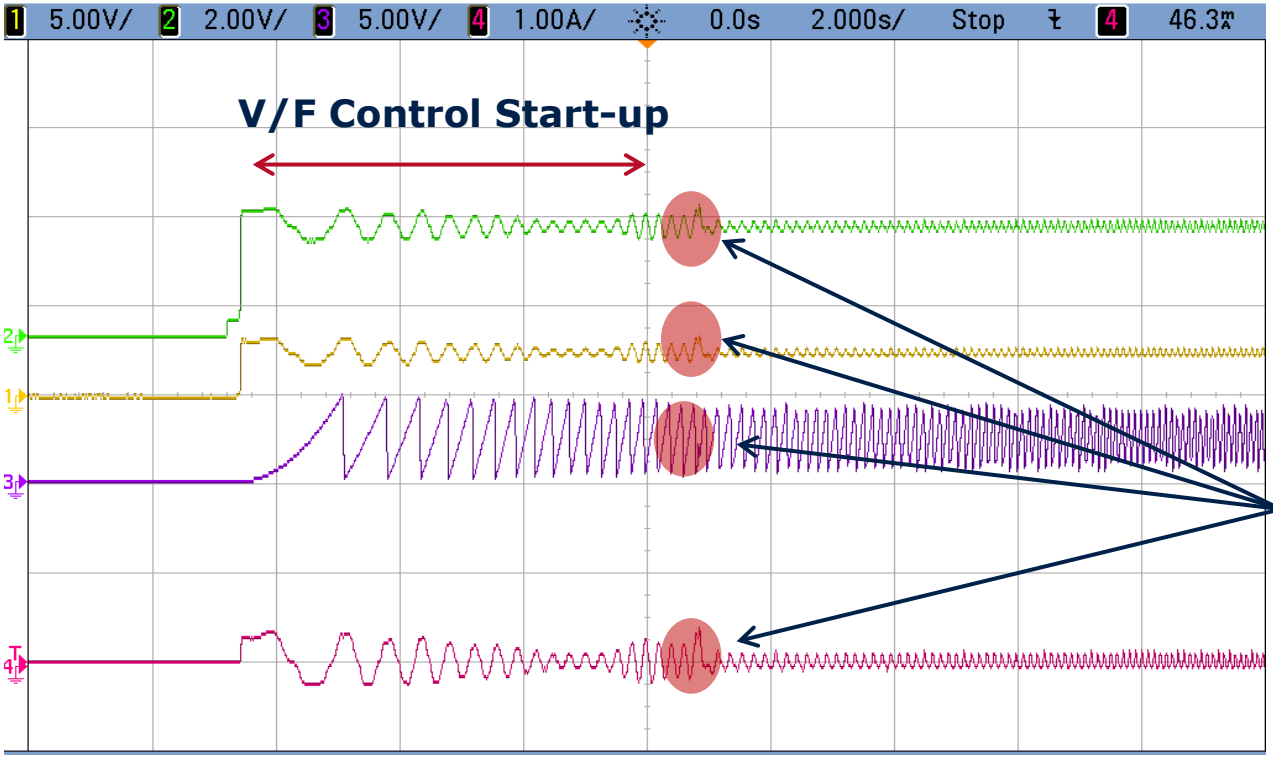
Chapter 4: Driving Ventilation Fan Application (16/17)

9. Below shows CCU4 output waveforms of Ventilation Fan while from V/F Open Loop to FOC Closed loop



- Transition Open Loop to Closed Loop at 100 rpm
- Transition at 11W

Channel 1 (yellow):- PMSMFOCSL02_Handle0.H_Ptr-> I_α

Channel 2 (green): - PMSMFOCSL02_Handle0.H_Ptr -> Iu

Channel 3 (blue): - PMSMFOCSL02_Handle0.H_Ptr -> Angle

Channel 4 (pink): Current of fan motor Phase U (measured by current probe, 0.1V/A)

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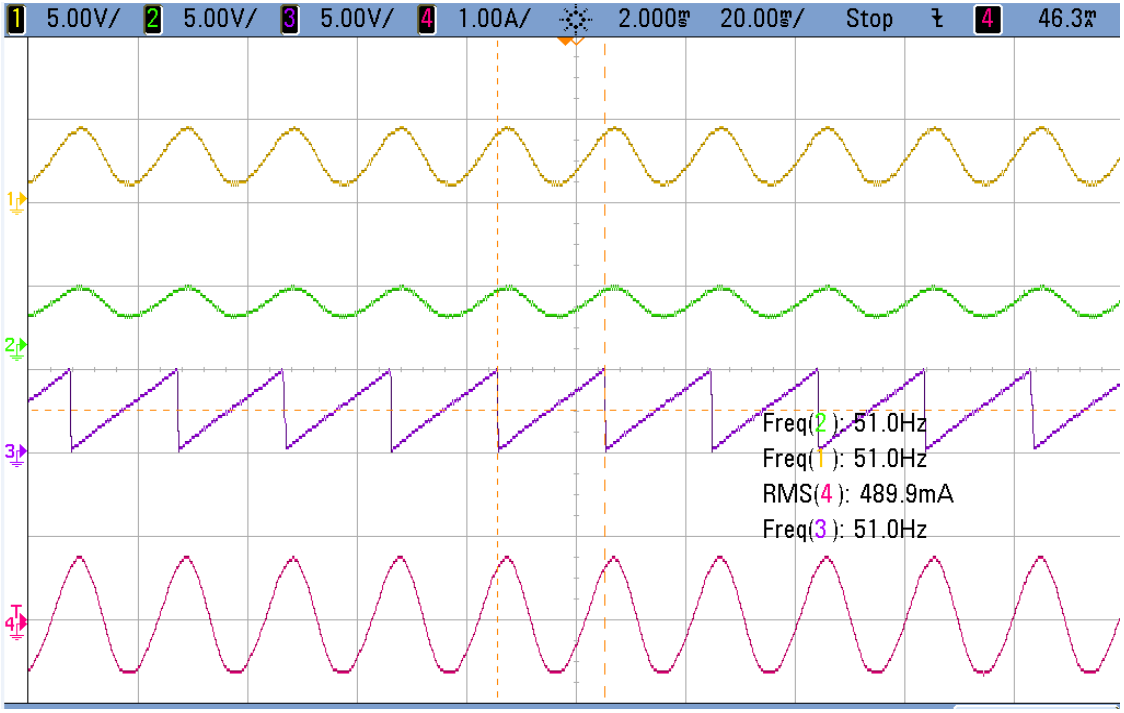
Chapter 4: Driving Ventilation Fan Application (17/17)

10. Below shows CCU4 output waveforms of Ventilation Fan running in FOC during steady state



- End Speed Reference = 1000 rpm
- Speed Slew Rate = 30 rpm/s
- Speed = $\frac{60\ x\ 51\ Hz}{3} = 1020\ rpm$

Channel 1 (yellow):- PMSMFOCSL02_Handle0.H_Ptr-> I_α

Channel 2 (green): - PMSMFOCSL02_Handle0.H_Ptr -> Iu

Channel 3 (blue): - PMSMFOCSL02_Handle0.H_Ptr -> Angle

Channel 4 (pink): Current of fan motor Phase U (measured by current probe, 0.1V/A)

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Agenda (1/2)

- Kit Overview
- Tooling Overview
- Getting Started
  - Chapter 1: Generate PMSMFOCSL02 template
  - Chapter 2: Configure CCU4 as Debugging feature
  - Chapter 3: Motor Electrical Parameters Measurement
  - Chapter 4: Driving Ventilation Fan Application
  - Chapter 5: Driving Ceiling Fan Application

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Chapter 5: Driving Ceiling Fan Application (1/20)

- Ceiling Fan Application Overview:
  - Microcontroller: Infineon XMC1302-T038X0200
  - Algorithm: Dual Shunt Sensorless FOC (PMSMFOCSL02)
  - Hardware: XMC 750 Watt Motor Control Application Kit (KIT_XMC750WATT_MC_AK_V1)
  - DC Link Voltage: 320 VDC
  - Fan Motor Specification:
    - Phase to Phase Resistance: **71.2 Ω**
    - Phase to Phase Inductance: **483 mH**
    - Pole Pairs: **6**
    - Tested Speed range: **30 rpm to 220 rpm**
    - Blade Size: **22.5”**

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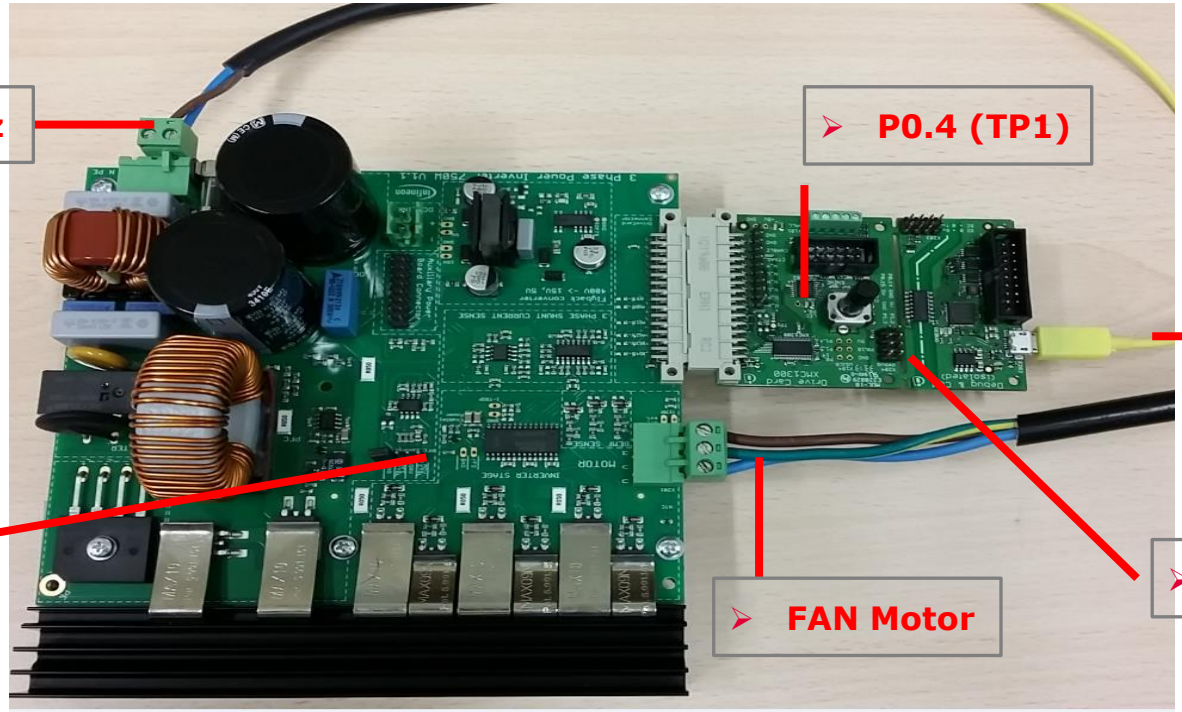
Chapter 5: Driving Ceiling Fan Application (2/20)

- This chapter provides a guideline on how to run Ceiling Fan application using PMSMFOCSL02
- TP1, TP2 and TP3 are test points to probe with oscilloscope
- Connect the motor phases to XMC 750 Watt Motor Control Application Kit as shown:



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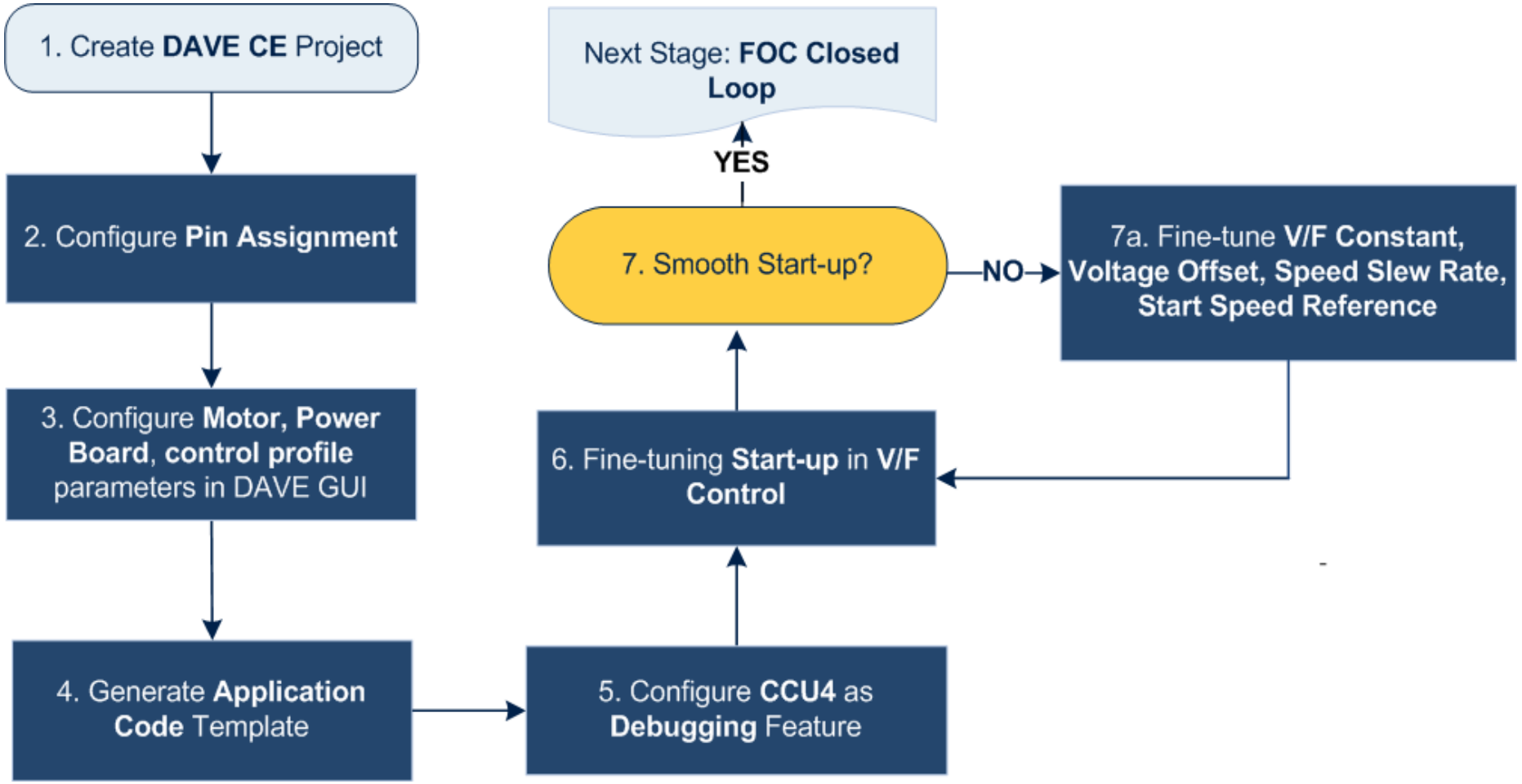
Chapter 5: Driving Ceiling Fan Application (3/20)



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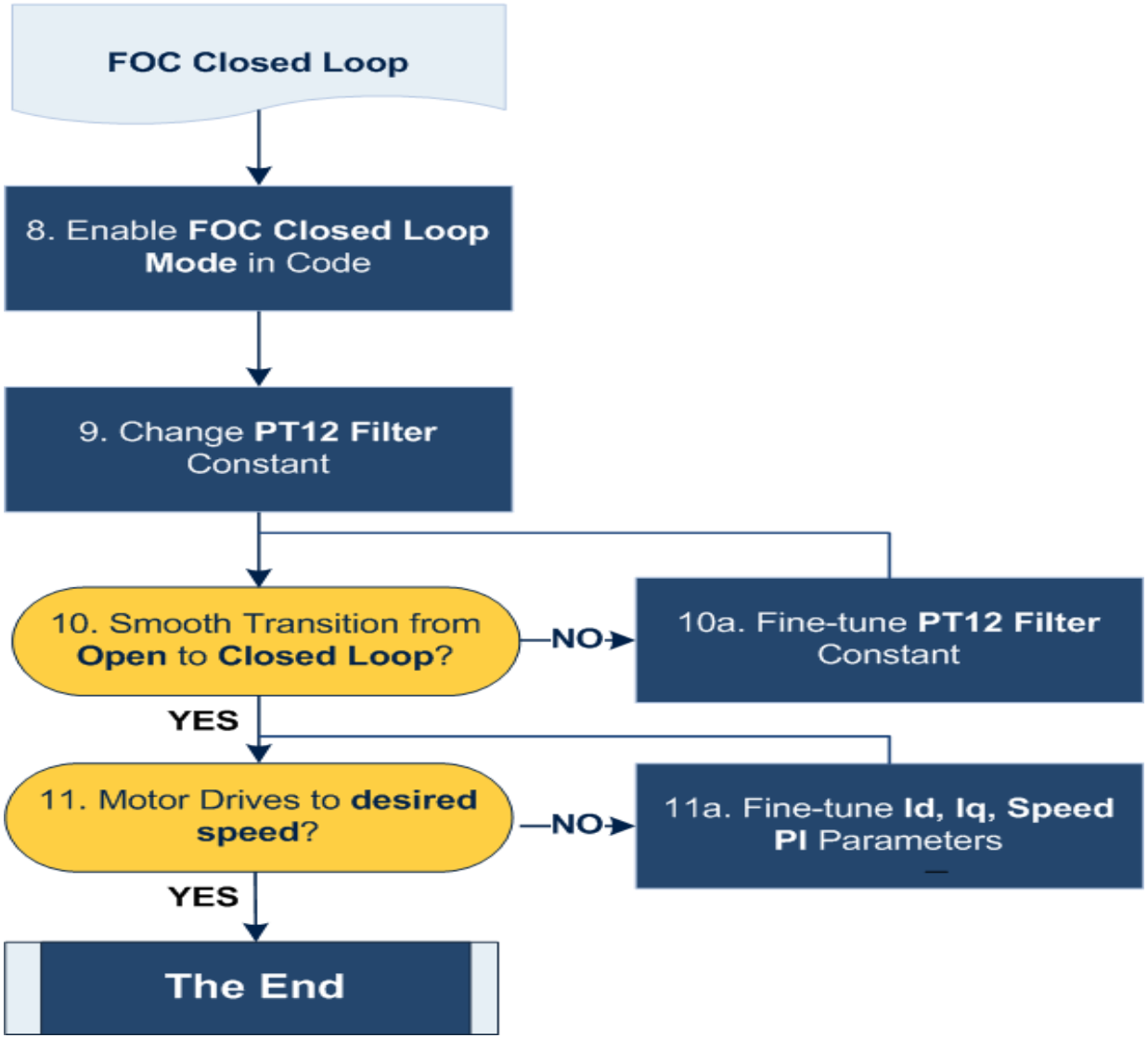
Chapter 5: Driving Ceiling Fan Application (4/20)



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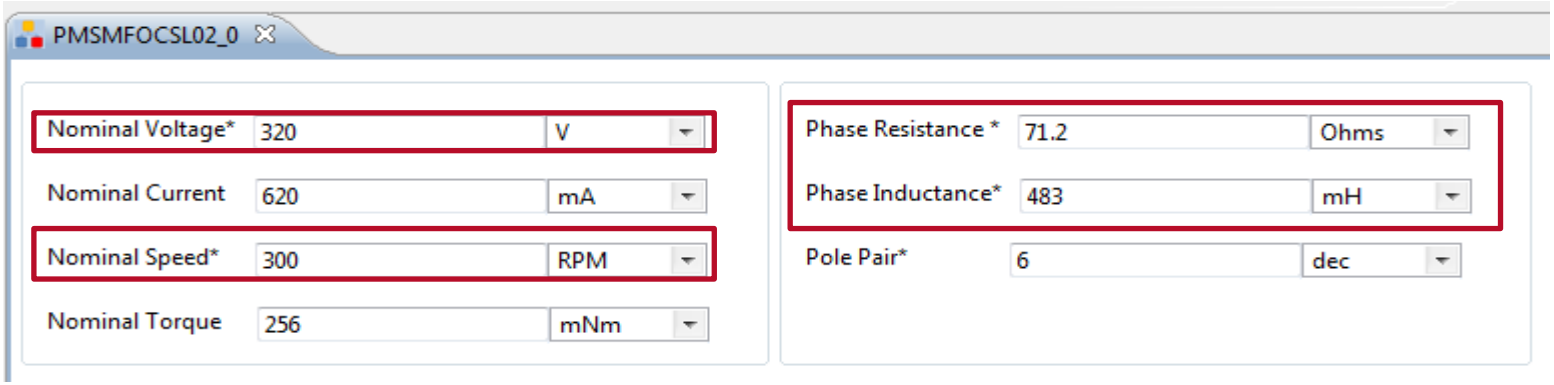
Chapter 5: Driving Ceiling Fan Application (5/20)

1. Create **DAVE CE** project - (page 15)
2. Configure **Pin Assignment** – (page 23)
3. Configure **Motor, power board, control profile parameters** in DAVE GUI
   - Keep default setting value in **Control Algorithm** tab
   - Click on **Motor Parameters** tab,



   - Configure Motor Nominal Voltage as **320V**
   - Nominal Speed set to **300 rpm**
   - Phase to phase resistance set to **71.2Ω**
   - Phase to phase inductance set to **483mH**
   - Pole Pairs of motor = **6**

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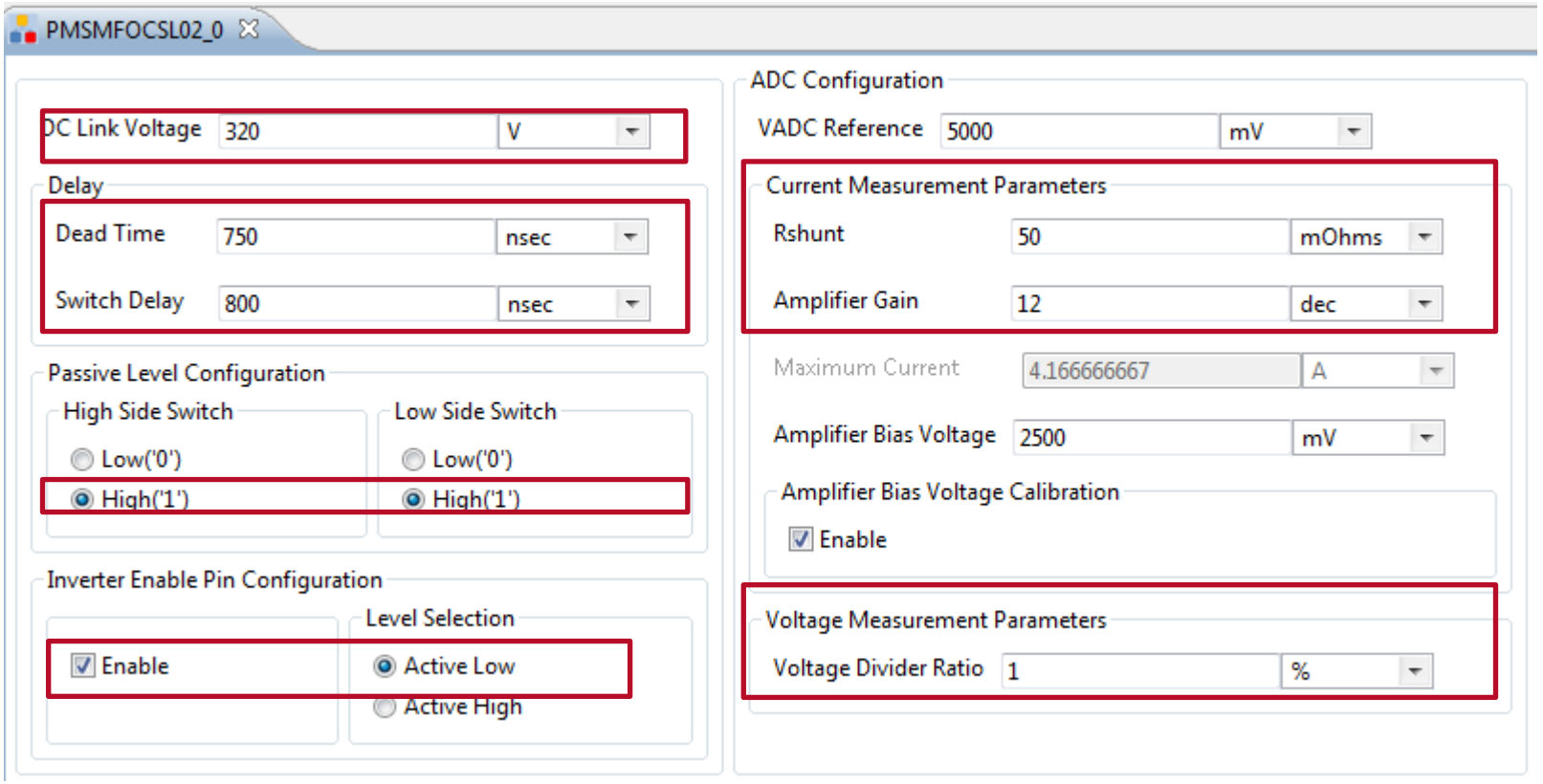
Chapter 5: Driving Ceiling Fan Application (6/20)

- Click on **Power Board** tab,



❖ Refer to page 16 or **750W Board User Manual** for hardware details

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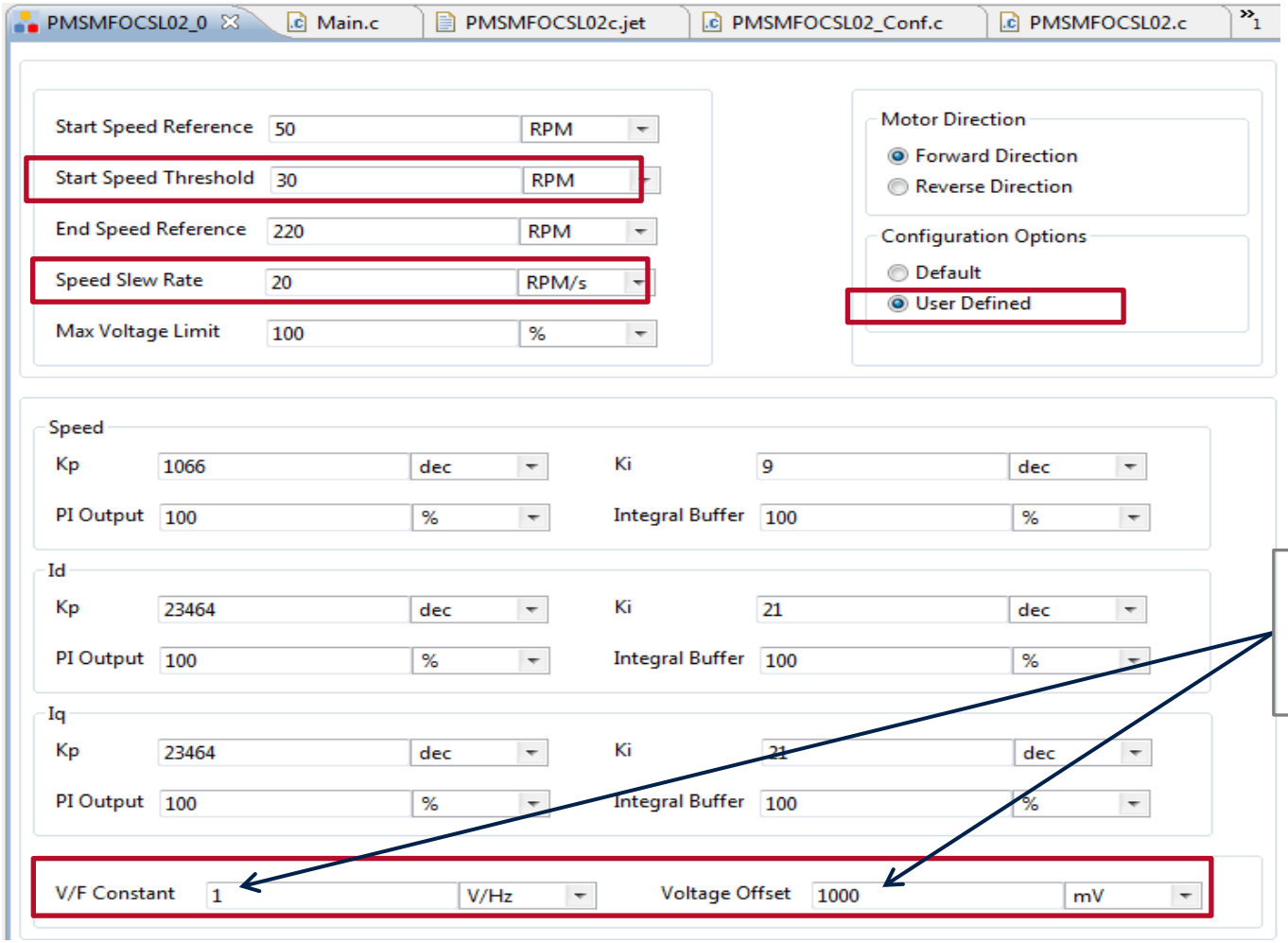
Chapter 5: Driving Ceiling Fan Application (7/20)

- Click on **Control Panel** tab, user should configure start-up parameters for V/F control



- Starting with lower start-up power

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Chapter 5: Driving Ceiling Fan Application (8/20)

4. Generate **Application Code** Template – Click
5. Configure CCU4 as Debugging Feature – (page 27 – page 29)
   - Following the steps to enable CCU4 debugging pin
   - Copy the attached **main.c** and paste into user's main.c
6. Fine-tuning Start-up in **V/F control**
   - V/F control principle consist in feeding the motor winding with a 3-phase sinusoidal voltage whose amplitude is proportional to the frequency and time.
   - Under C/C++ projects -> Dave -> Generated -> src -> PMSMFOCSL02.c, search for **PMSMFOCSL02_SpeedRampup()** API function.
   - **Grey out** the 5 code lines as shown:

```
        else
        {
          HandlePtr->H_Ptr->SpeedRef--;
        }
        SET_BIT(HandlePtr->H_Ptr->MotorStatus, PMSMFOCSL02_RAMP_Pos);
      }
      else
      {
//        CLR_BIT(HandlePtr->H_Ptr->MotorStatus,PMSMFOCSL02_OL_Pos);
//        SET_BIT(HandlePtr->H_Ptr->MotorStatus, PMSMFOCSL02_FOC_Pos);
//        HandlePtr->SpeedPT1Ptr->PT1buf = HandlePtr->H_Ptr->SpeedRef<<16;
//        HandlePtr->H_Ptr->State=PMSMFOCSL02_RUNNING;
//        HandlePtr->H_Ptr->SpeedControlRate = (uint32_t)0;
      }
    }
```


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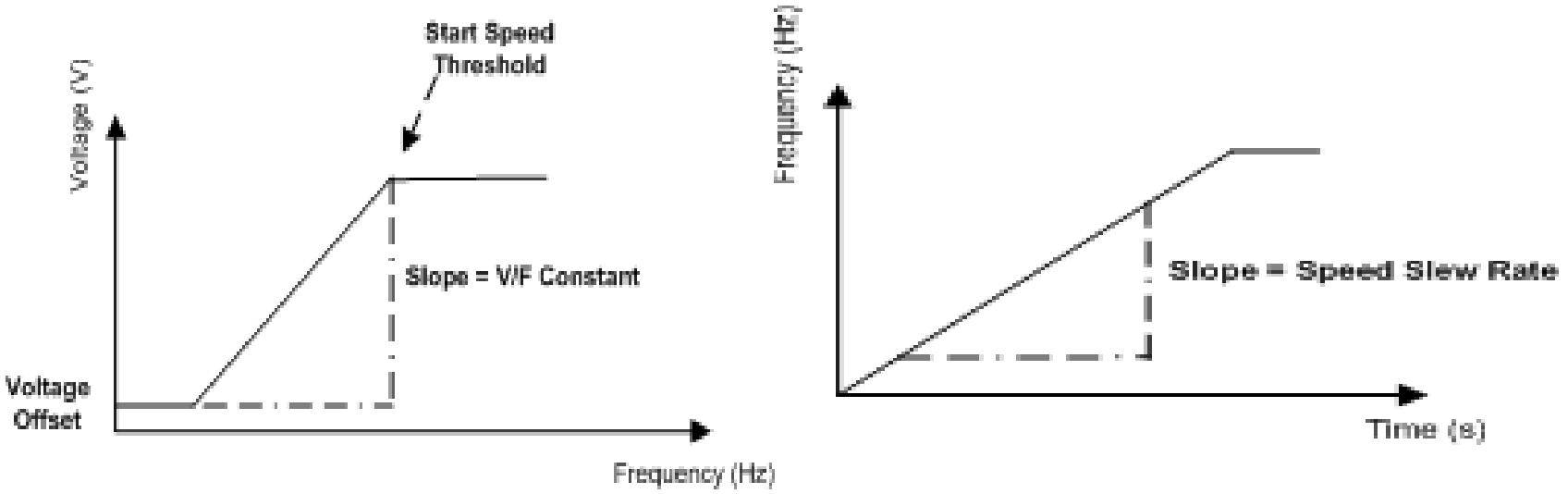
Chapter 5: Driving Ceiling Fan Application (9/20)

- Place 3 signal probes on **P0.4, P0.5, P1.2** on hardware
- Take note that the start-up current would be **HIGH** if user configure motor start-up parameters wrongly. User can always **limit the current** in power supply
- It's recommended to start with **LOW** V/F constant & Voltage Offset. (V/F constant = 1.0 V/Hz, Voltage Offset = 1000 mV)
- The start-up response will be **affected** by Speed Slew Rate, Start Speed Threshold, V/F Constant, Voltage Offset



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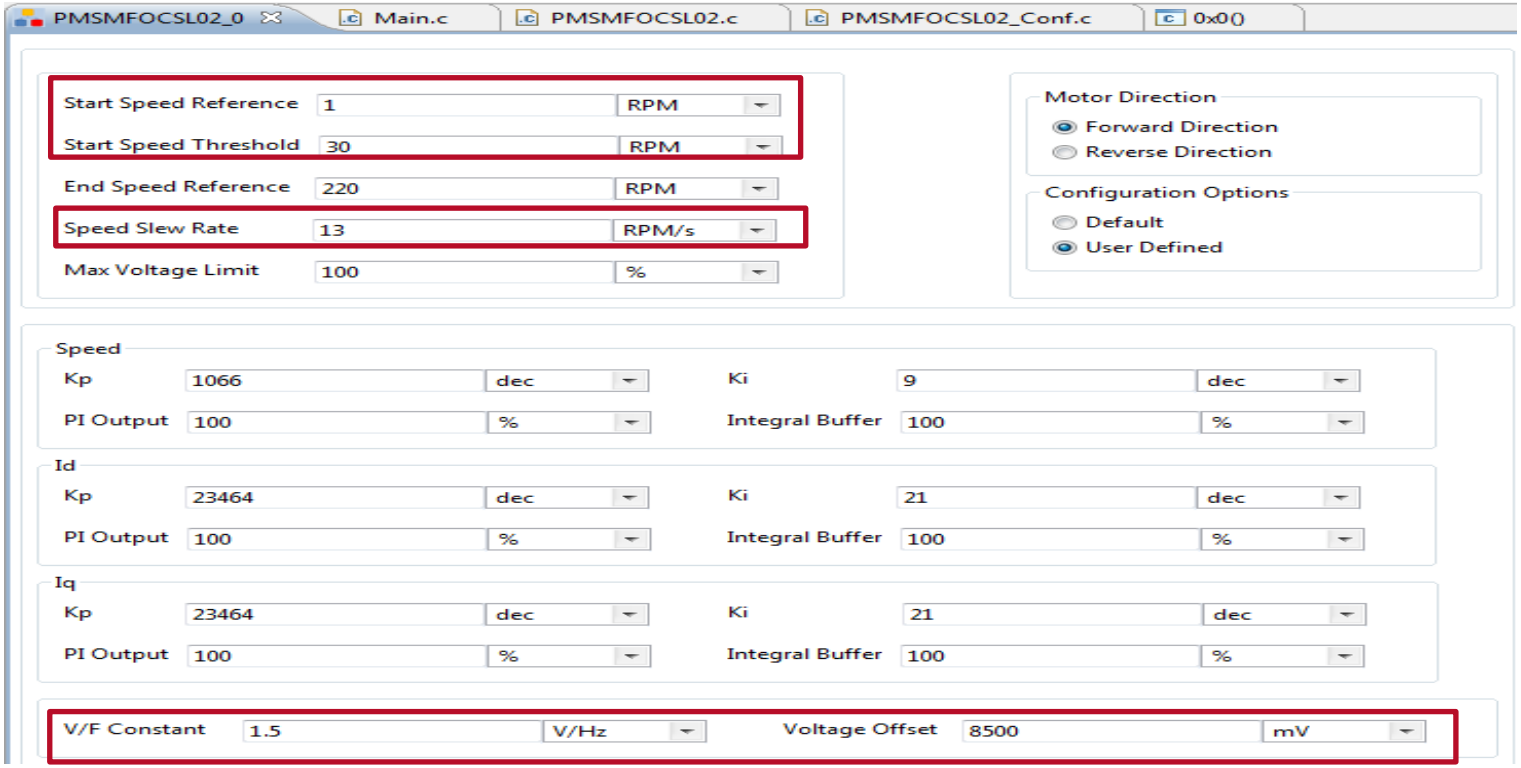
Chapter 5: Driving Ceiling Fan Application (10/20)

7. Evaluate the motor start-up response, repeat fine-tuning steps if necessary.

   - User may reconfigure the **4 parameters** in App GUI, regenerate code is needed for every changes in GUI



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Chapter 5: Driving Ceiling Fan Application (11/20)

- User may change the **RED** highlighted variables to improve the start-up response

```
PMSMFOCSL02_StartupHandleType PMSMFOCSL02_StartupHandle0 =
{
  .VFOffset  =(uint32_t)708,
  .VFConst   =(uint32_t)1084,
  .Angle     =(int16_t)0
};

PMSMFOCSL02_DynamicHandleType PMSMFOCSL02_DynamicHandle0 =
{
  .IqStartup    =(uint32_t)500,
  .State              = PMSMFOCSL02_UNINITIALIZED
};
```

PMSMFOCSL02_0 | Main.c | PMSMFOCSL02.c | PMSMFOCSL02_Conf.c | 0x0()

```
198
199  .kNormkp             = (uint32_t)512,
200
201  .kNormki             = (uint32_t)32767,
202
203  .kNormSpeed          = (uint32_t)11110,
204
205  .kNormCurrent        =(uint32_t)33,
206
207  .kNormCurrentAlphaBeta=(uint32_t)66,
208
209  .kNormCurrentdq      =(uint32_t)80,
210
211  .kNormSlewRate       =(uint32_t)10171,
212
213  .kAmplitudeMax       =(uint32_t)13329,
214
215  .kAmplitudeMin       =(uint32_t)0,
216
217  .kUserStartSpeedRef  =(int32_t)2,
218  .kUserStartSpeedThreshold  = (int32_t)88,
219
220  .kUserEndSpeedRef    =(int32_t)648,
221
222  .kSpeedMaxTarget     =(uint32_t)884,
223
224  .kRampCounter        =(uint32_t)782,
225
226  .kSlewRate           =(uint32_t)13,
227
228  .kSpecifiedVolt      =(uint32_t)2621,
229
230  .kPolePair           =(uint32_t)6,
231
```

- The main advantage: Save up compilation time during fine-tuning
- High inertia motor requires higher start-up power

Refer to page 21 to set **code optimization level** in DAVE before user download hex code into XMC1300

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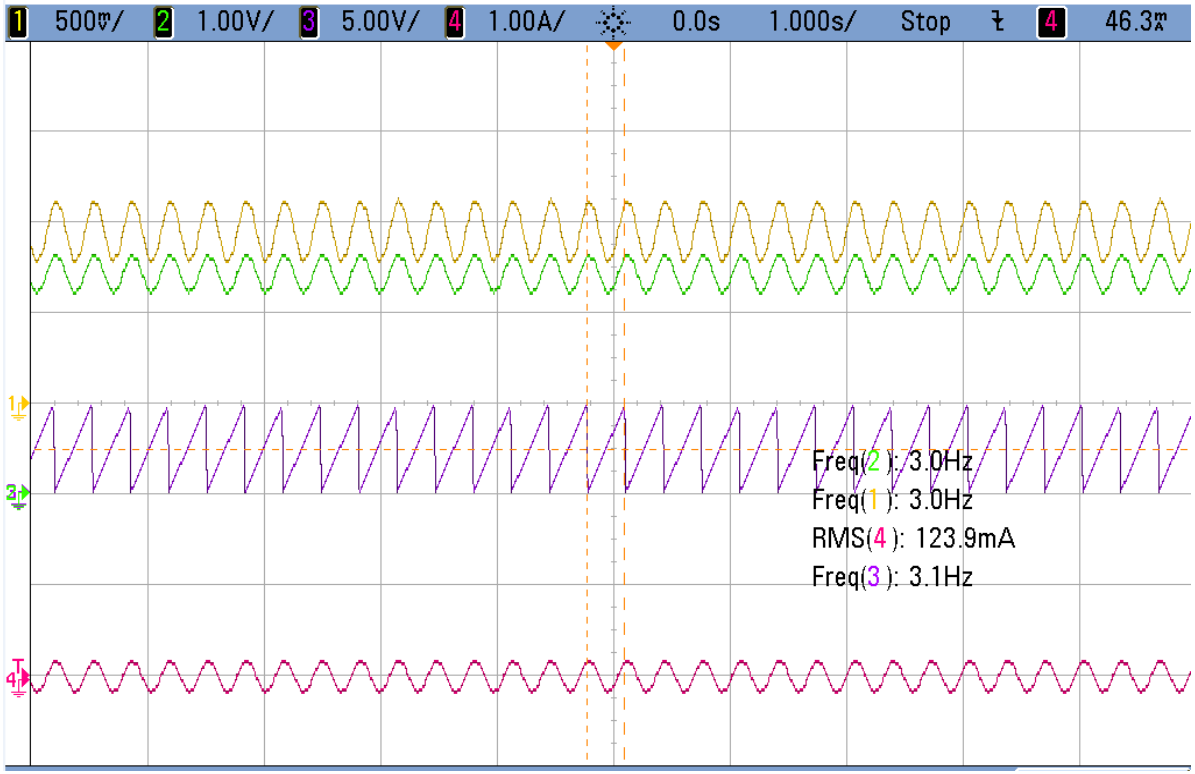
Chapter 5: Driving Ceiling Fan Application (12/20)

- Below shows CCU4 output waveform of Ventilation Fan while running in V/F control Start-up



- Motor Speed = 30 rpm

Channel 1 (yellow):- PMSMFOCSL02_Handle0.H_Ptr-> I_α

Channel 2 (green): - PMSMFOCSL02_Handle0.H_Ptr -> Iu

Channel 3 (blue): - PMSMFOCSL02_Handle0.H_Ptr -> Angle

Channel 4 (pink): Current of fan motor Phase U (measured by current probe, 0.1V/A)

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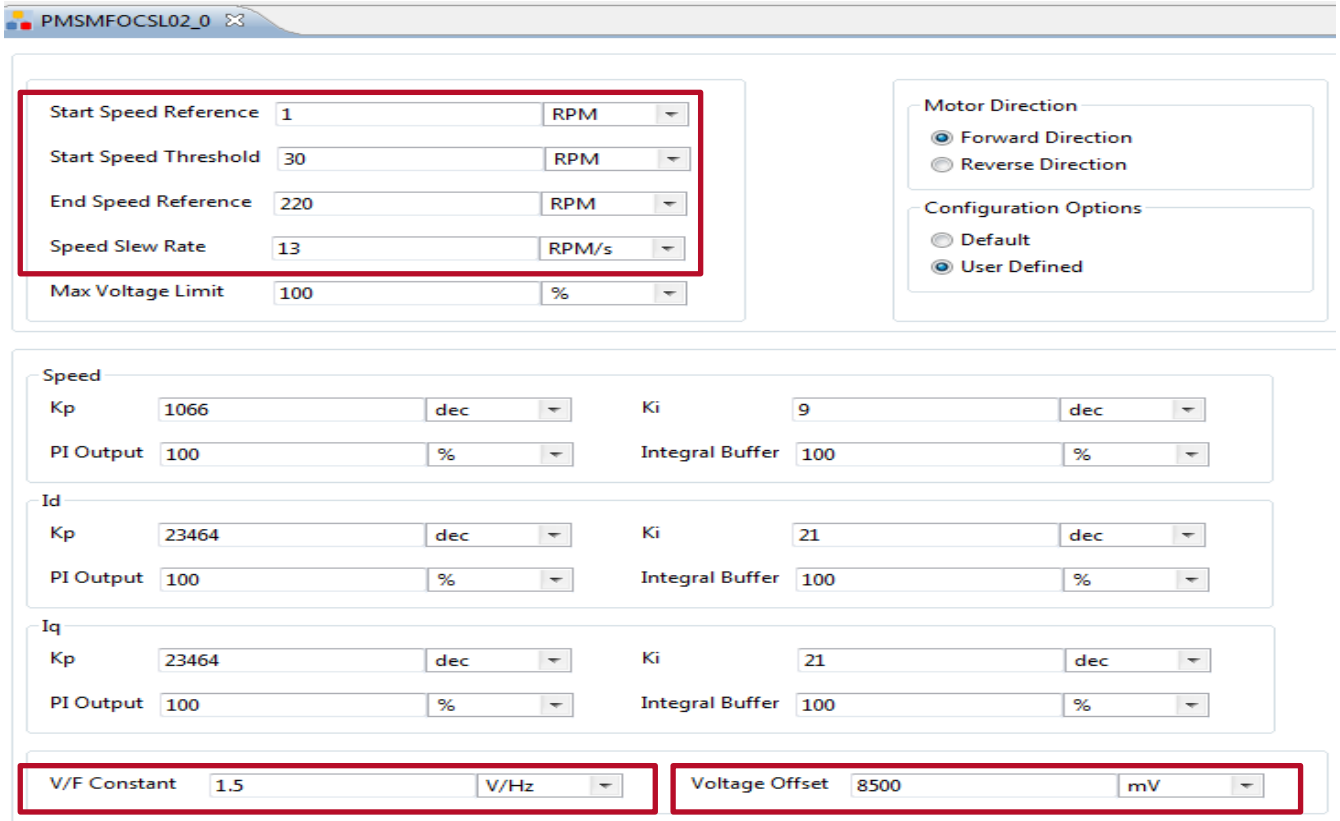
Chapter 5: Driving Ceiling Fan Application (13/20)

- Screenshot of typical V/F parameters value in DAVE App



- The Start-up parameters shown are mainly for references purpose. Due to differences between various motor, the V/F control parameters needs to be tuned to drive every new motor model

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Chapter 5: Driving Ceiling Fan Application (14/20)

8. The **FOC Closed Loop** operation can be **ENABLED** by **uncommenting** the 5 lines highlighted as below:

   - Under C/C++ projects -> Dave -> Generated -> src -> PMSMFOCSL02.c, search for **PMSMFOCSL02_SpeedRampup()** API function.

```
        else
        {
          HandlePtr->H_Ptr->SpeedRef--;
        }
        SET_BIT(HandlePtr->H_Ptr->MotorStatus, PMSMFOCSL02_RAMP_Pos);
      }
      else
      {
//      CLR_BIT(HandlePtr->H_Ptr->MotorStatus,PMSMFOCSL02_OL_Pos);
//      SET_BIT(HandlePtr->H_Ptr->MotorStatus, PMSMFOCSL02_FOC_Pos);
//      HandlePtr->SpeedPI1Ptr->PI1buf = HandlePtr->H_Ptr->SpeedRef<<16;
//      HandlePtr->H_Ptr->State=PMSMFOCSL02_RUNNING;
//      HandlePtr->H_Ptr->SpeedControlRate = (uint32_t)0;
      }
    }
```

- Skip the following page 50 to page 52 if user is using **PMSMFOCSL02[1.0.8]** and above
- **Id** and **Iq KpKI** values in App GUI are calculated based on motor resistance and inductance values. Speed PI Kp and KI are not calculated, it is hardcoded values.

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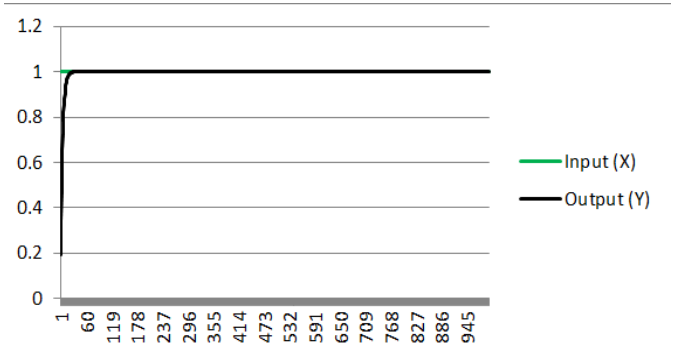
Chapter 5: Driving Ceiling Fan Application (15/20)

9. Fine-tune PT12 Filter Constant for better performance

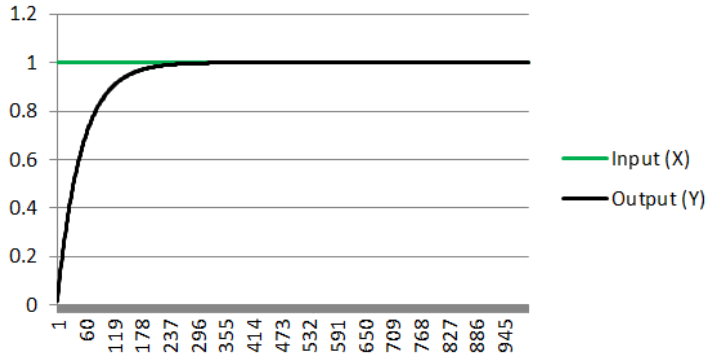
- The integration of the induced voltage during the calculation of the **flux Ψ** is calculated by a low pass filter of first order which is realized by a PT12 controller.
- Given PT12 controller formula as:

$$\mathbf{Y[n] = Y[n-1] + Z1 * X[n] – Z2 * Y[n-1]}$$

- For example, assume X[1] = 1, user can fine-tune the **Z1** value and **Z2** value. The response time can be modified.



■ Z1 = 6367, Z2 = 636



■ Z1 = 636, Z2 = 63

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Chapter 5: Driving Ceiling Fan Application (16/20)

- User would require to modify the **PMSMFOCSL02_Config.c** to change the response time to drive different motors.
- To fine-tune the PT12 filter gain, additional user code needs to be added as shown below:

```
108 #define Z1_MULTIPLY 6
109 #define Z1_DIVIDE   10
110 #define Z2_MULTIPLY 1
111 #define Z2_DIVIDE   10
112
113 MOTORLIBS_PT1HandleType_PMSMFOCSL02_PT12alphaHandle0 = {
114   .Z1    =(int32_t)6367*Z1_MULTIPLY/Z1_DIVIDE,
115   .Z2    =(int32_t)636*Z2_MULTIPLY/Z2_DIVIDE,
116   .Ymax  =(int32_t)(0x70000000),
117   .Ymin  =(int32_t)(-0x70000000),
118   .PT1buf=(int32_t)0
119 };
120 MOTORLIBS_PT1HandleType_PMSMFOCSL02_PT12betaHandle0 = {
121   .Z1    =(int32_t)6367*Z1_MULTIPLY/Z1_DIVIDE,
122   .Z2    =(int32_t)636*Z2_MULTIPLY/Z2_DIVIDE,
123   .Ymax  =(int32_t)(0x70000000),
124   .Ymin  =(int32_t)(-0x70000000),
125   .PT1buf=(int32_t)0
126 };
127
```

- User can fine-tune **Z1_MULTIPLY** variable for other PMSM motors.

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Chapter 5: Driving Ceiling Fan Application (17/20)

- Besides, user needs to change -2 to -4 for both **PMSMFOCSL02_Handle0.H_Ptr->Ia** and **PMSMFOCSL02_Handle0.H_Ptr->Ib** in **PMSMFOCSL02.c**

```
/*
 *This is user define interrupt handler for period match interrupt
 */
void PMSMFOCSL02_PWMPeriodMatchISR0(void)
{


  /*Reading Phase-U current*/
  PMSMFOCSL02_Handle0.H_Ptr->Ia =
     (((ADCCH001_HandleType *)PMSMFOCSL02_Handle0.ADCReqSrcPtrA->kChAHandlerPtr)->ADCGrPtr->
         RES[((ADCCH001_HandleType *)PMSMFOCSL02_Handle0.ADCReqSrcPtrA->kChAHandlerPtr)->kStartResultRegNo] & VADC_G_RE
  PMSMFOCSL02_Handle0.H_Ptr->Ia = -2*(int32_t)((PMSMFOCSL02_Handle0.H_Ptr->Ia)-PMSMFOCSL02_Handle0.H_Ptr->AmpOffset);

  /*Reading Phase-V current*/
  PMSMFOCSL02_Handle0.H_Ptr->Ib =
     (((ADCCH001_HandleType *)PMSMFOCSL02_Handle0.ADCReqSrcPtrB->kChBHandlerPtr)->ADCGrPtr->
         RES[((ADCCH001_HandleType *)PMSMFOCSL02_Handle0.ADCReqSrcPtrB->kChBHandlerPtr)->kStartResultRegNo] & VADC_G_RE
  PMSMFOCSL02_Handle0.H_Ptr->Ib = -2*(int32_t)((PMSMFOCSL02_Handle0.H_Ptr->Ib)-PMSMFOCSL02_Handle0.H_Ptr->AmpOffset);
```

```
/*
 *This is user define interrupt handler for period match interrupt
 */
void PMSMFOCSL02_PWMPeriodMatchISR0(void)
{


  /*Reading Phase-U current*/
  PMSMFOCSL02_Handle0.H_Ptr->Ia =
     (((ADCCH001_HandleType *)PMSMFOCSL02_Handle0.ADCReqSrcPtrA->kChAHandlerPtr)->ADCGrPtr->
         RES[((ADCCH001_HandleType *)PMSMFOCSL02_Handle0.ADCReqSrcPtrA->kChAHandlerPtr)->kStartResultRegNo] & VADC_G_RE
  PMSMFOCSL02_Handle0.H_Ptr->Ia = -4*(int32_t)((PMSMFOCSL02_Handle0.H_Ptr->Ia)-PMSMFOCSL02_Handle0.H_Ptr->AmpOffset);

  /*Reading Phase-V current*/
  PMSMFOCSL02_Handle0.H_Ptr->Ib =
     (((ADCCH001_HandleType *)PMSMFOCSL02_Handle0.ADCReqSrcPtrB->kChBHandlerPtr)->ADCGrPtr->
         RES[((ADCCH001_HandleType *)PMSMFOCSL02_Handle0.ADCReqSrcPtrB->kChBHandlerPtr)->kStartResultRegNo] & VADC_G_RE
  PMSMFOCSL02_Handle0.H_Ptr->Ib = -4*(int32_t)((PMSMFOCSL02_Handle0.H_Ptr->Ib)-PMSMFOCSL02_Handle0.H_Ptr->AmpOffset);
```


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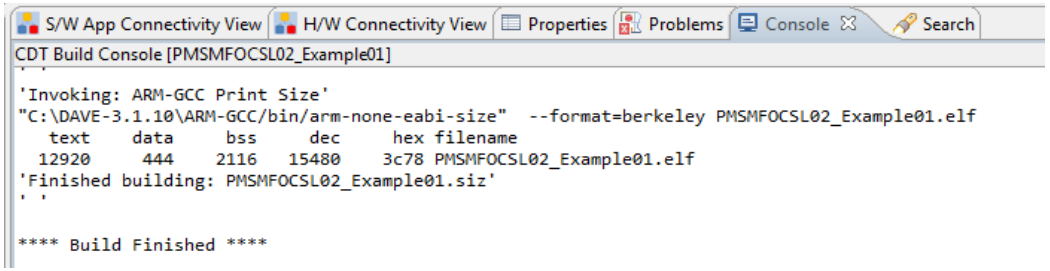
Chapter 5: Driving Ceiling Fan Application (18/20)

10. In this stage, the motor will be driven in FOC Closed Loop.

- Build project
  1. Click , Wait for Build to finish



- Download code
  1. Click & click to run the motor

- User should monitor the transition current waveform to fine-tune **Z1_MULTIPLY** to reduce vibration, current spike and etc

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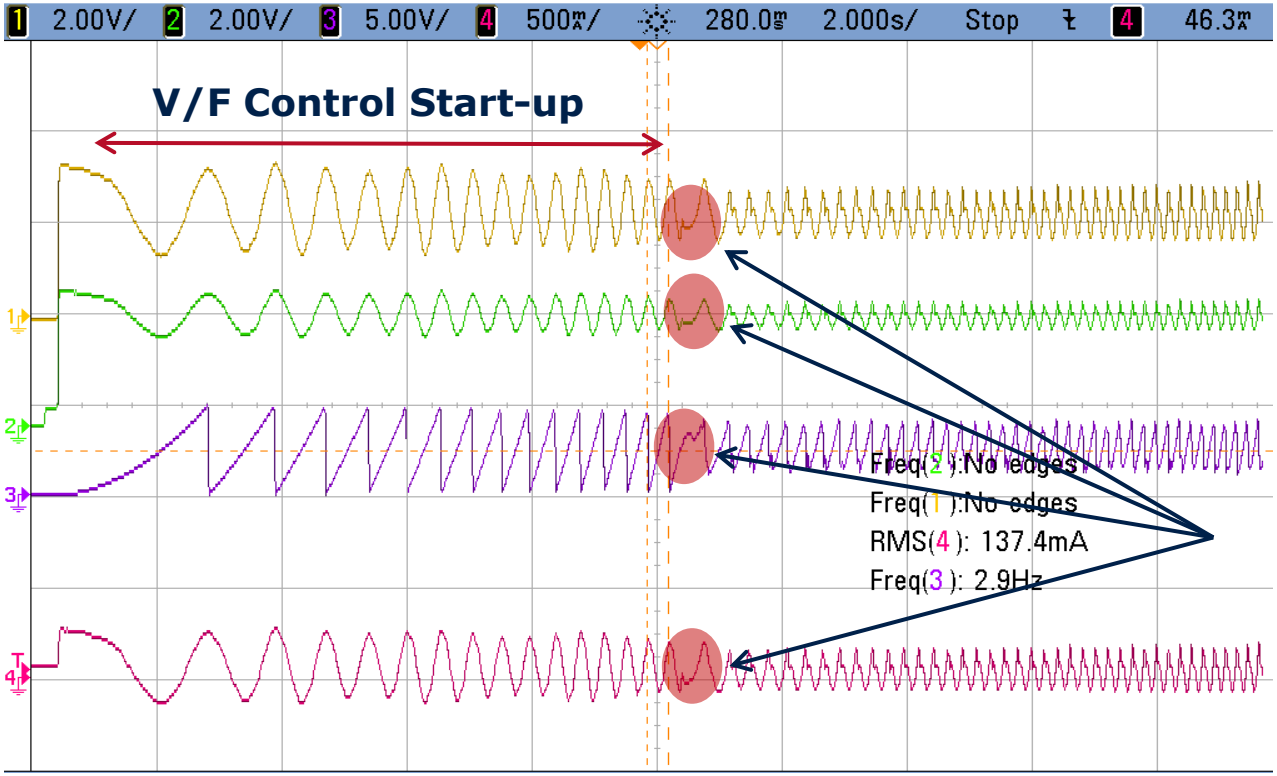
Chapter 5: Driving Ceiling Fan Application (19/20)

- Below shows CCU4 output waveforms of Ceiling Fan while from V/F Open Loop to FOC Closed loop



- Transition Open Loop to Closed Loop at 30 rpm

Channel 1 (yellow):- PMSMFOCSL02_Handle0.H_Ptr-> I_α

Channel 2 (green): - PMSMFOCSL02_Handle0.H_Ptr -> Iu

Channel 3 (blue): - PMSMFOCSL02_Handle0.H_Ptr -> Angle

Channel 4 (pink): Current of fan motor Phase U (measured by current probe, 0.1V/A)

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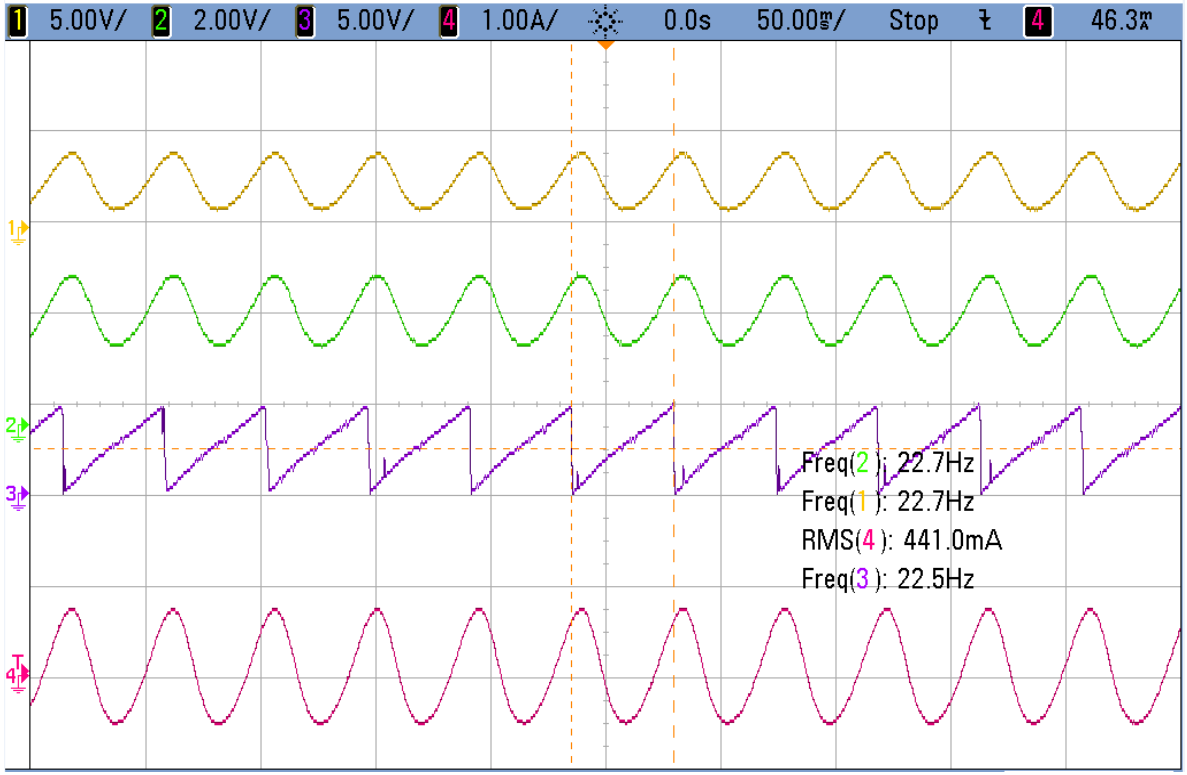
Chapter 5: Driving Ceiling Fan Application (20/20)

- Below shows CCU4 output waveforms of Ceiling Fan running in FOC during steady state



- End Speed Reference = 220 rpm
- Speed Slew Rate = 13 rpm/s
- Speed = $\frac{60\ x\ 22.7\ Hz}{6} = 227\ rpm$

Channel 1 (yellow):- PMSMFOCSL02_Handle0.H_Ptr-> I_α

Channel 2 (green): - PMSMFOCSL02_Handle0.H_Ptr -> Iu

Channel 3 (blue): - PMSMFOCSL02_Handle0.H_Ptr -> Angle

Channel 4 (pink): Current of fan motor Phase U (measured by current probe, 0.1V/A)

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Agenda (2/2)

- Summary
- General Information
- References
  - Where to find Apps documentation?
  - Where to download example projects?
  - How to load Example project in DAVE?
  - How to improve compiler performance?

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Summary

- This document provides effective techniques for tuning the PMSMFOCSL02 App in DAVE for running high voltage PMSM motor
- This procedure are more robust and should cover the requirements of most ventilation fan and ceiling fan applications

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Agenda (2/2)

- Summary
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General Information

- Where to buy kit:
  - http://www.ehitex.de/XMC-750-Watt-Motor-Control-Application-Kit_detail_469.html
  - Order Number: KIT_XMC750WATT_MC_AK_V1
- Kit documentation:
  - KIT_XMC750WATT_MC_AK_V1
- Infineon parts utilized on kit:

Infineon Parts	Order Number
XMC1300 Microcontroller	XMC1302-T038X-0200
LDO 500mA	IFX1763
Standalone PFC Controller	ICE3PCS02
Offline SMPS Current Mode Controller	ICE3B0365JG (Discontinued) ICE3BR4765JG (Replacement)
Gate Drive IC	6ED003L06-F
High Speed DuoPack IGBT	IKB20N60H3
IGBT with integrated diode	IKD10N60R

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Agenda (2/2)

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  - How to load Example project in DAVE?
  - How to improve compiler performance?

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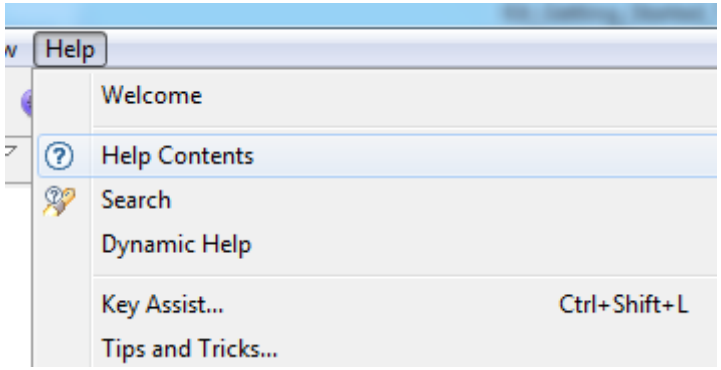
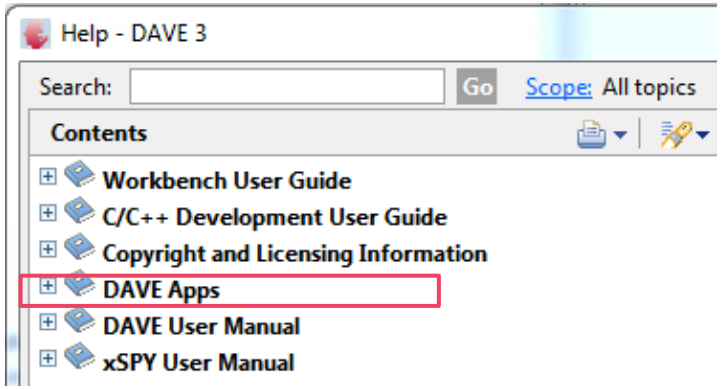
References – Where to find App Documentation?

- Go to **Help** -> **Help Contents**
- Go to **DAVE Apps** -> Expand topics -> Clck on **IO004** (latest version)
- Click on **IO004 App** -> **Overview**





Usage information found under xx App -> "Deployment and usage view"

Usage:

1. ACIMVF01 is initialized by the **ACIMVF01_Init()** function which is called by the DAVE_Init().
2. Call **ACIMVF01_MotorStart()** function to start the motor.
3. Direction and Speed can be changed at runtime using APIs **ACIMVF01_SetMotDirection()** and **ACIMVF01_SetEndSpeedRef()**.
4. Ramp up, V/F control, current measurement, DC link voltage measurement and POT measurement are executed in the PWM period match interrupt.
5. Trap interrupt handler handles the trap condition by stopping the motor.
6. Motor status can we read by using API **ACIMVF01_GetMotStatus()**. This is bit field level information. Please refer to the **ACIMVF01_DynamicHandleType** for details.

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References – Where to download Example Projects? (1/2)

- Two sets of Example Projects available
  - Additional Application Examples
    - Can be downloaded directly from the web
  - DAVE™ Project Library Examples
    - Can be downloaded from library in DAVE™
    - Can also be downloaded directly from the web

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References – Where to download Example Projects? (2/2)

- Additional Application Examples available
  - Running LEDs Example (Simple_XMC1100_RunningLEDs.zip)
  - UART Example (Simple_XMC1100_UART.zip)

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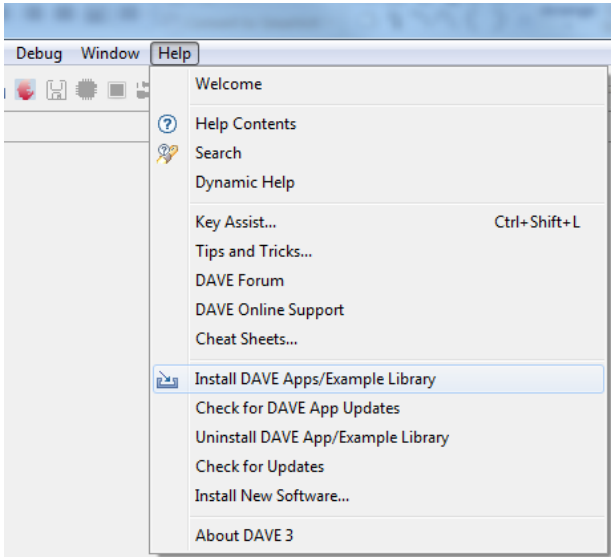
References – How to load Example Project in DAVE™? (1/5)

- Download Example Projects via DAVE™ library store
  - Help → Install DAVE Example Library



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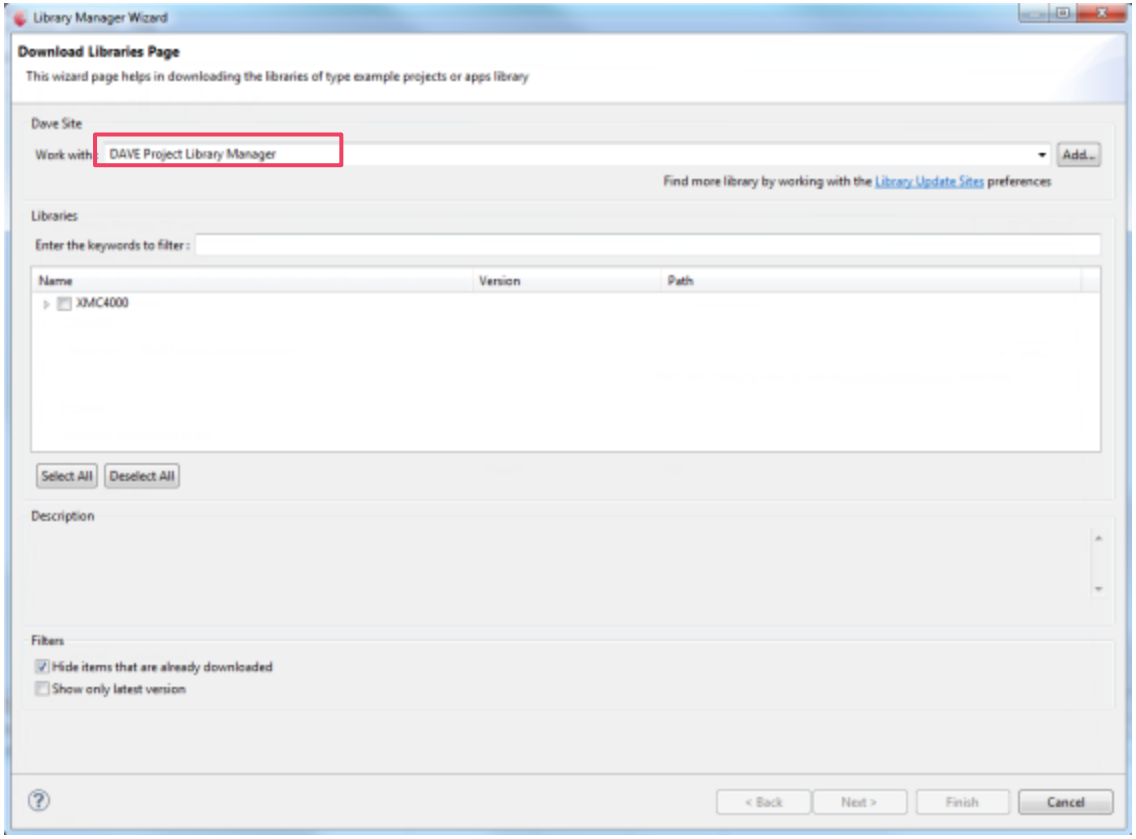
References – How to load Example Project in DAVE™? (2/5)

- Select DAVE Project Library Manager in the drop-down menu



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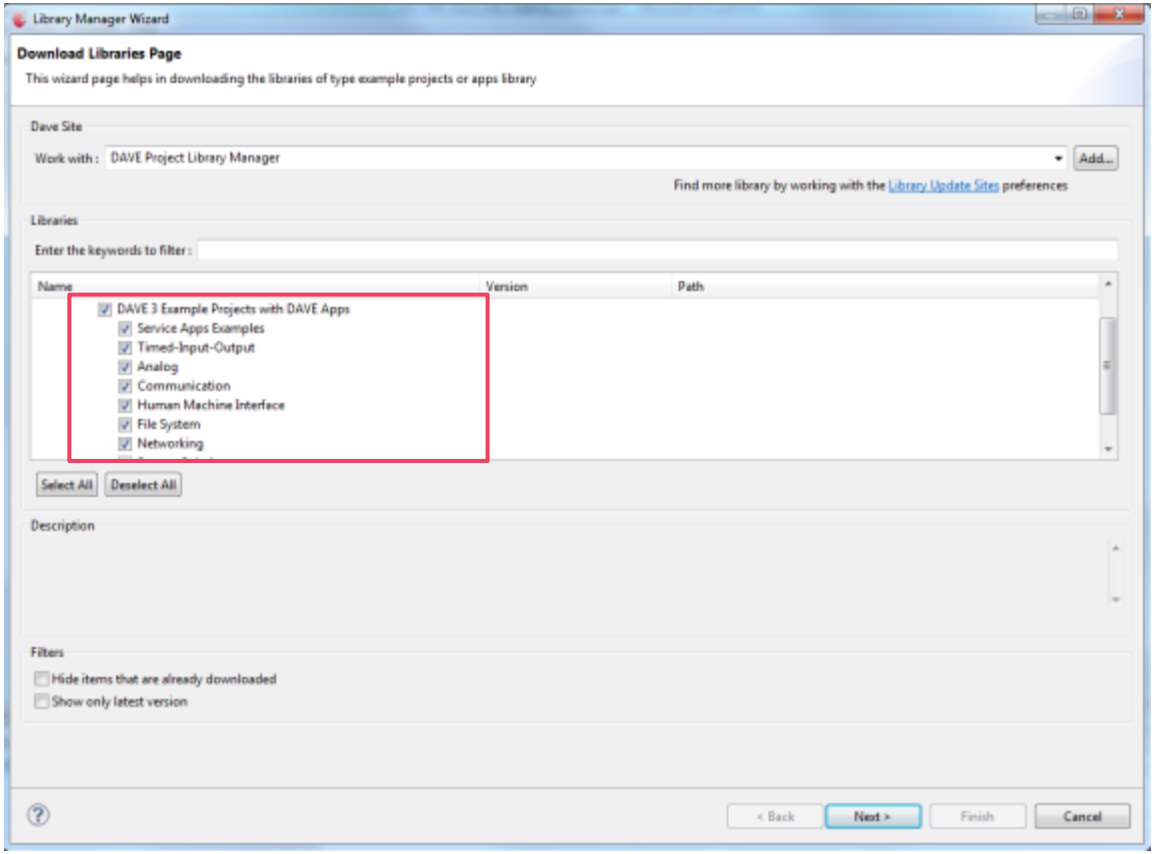
References – How to load Example Project in DAVE™? (3/5)

- Select Examples in the Libraries window and click Next



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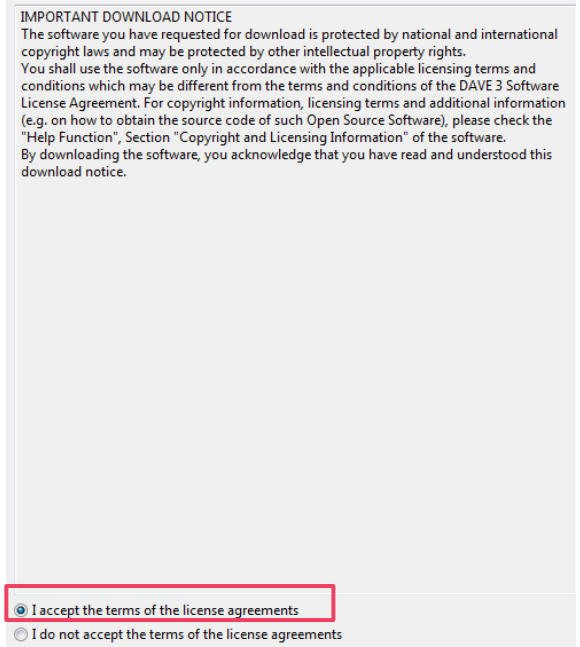
References – How to load Example Project in DAVE™? (4/5)

- Accept terms of the license agreements and click Finish



- DAVE Example Projects are installed

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References – How to load Example Project in DAVE™? (5/5)

- Download Example Projects from the web

http://www.infineon.com/cms/en/product/promopages/aim-mc/dave_downloads.html

Download the project zip file

- Download the project zip file
- Open DAVE™ and go to File → Import → Infineon → DAVE Project
- Check "Select Archive File"
- Browse to the downloaded DAVE project zip file
- Press "Open"

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References – How to improve compiler performance?

- Please refer to Infineon official XMC forum to explore how to speed up DAVE compilation time. It provides a couple of options that give perceivable improved speed.
- How to improve compiling feature discussion thread:

http://www.infineonforums.com/threads/1647-Improve-compiler-performance

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